8th INTERNATIONAL CONFERENCE ON STRENGTH TRAINING

Oslo, 24th - 28th of October 2012

ICST • 2012
NORWEGIAN SCHOOL OF SPORT SCIENCES

NORWEGIAN SCHOOL OF SPORT SCIENCES

FORSKNINGSSENTER FOR TRENING & PRESTASJON

OLYMPIATOPPEN

SAMMEN OM DE STORE PRESTASJONENE

Antidoping NORGE

8th International Conference on Strength Training

October 24th - 28th, 2012

Oslo, Norway

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Organized by

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Norwegian School of Sport Sciences
Forskningsenter for Trening og Presetasjon
Antidoping Norge
Olympiatoppen

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Welcome to the 8th International Conference on Strength Training (ICST 2012)

On behalf of the Norwegian School of Sport Sciences, we are happy to welcome you to the 8th International Conference on Strength Training. The Norwegian School of Sport Science is honored to organize this important event. We hope the conference will be fulfilling professionally, and that you will have time to enjoy some of the sites and recreational activities available in the city of Oslo and the surrounding area.

The major goal of this international scientific conference is to present and discuss the most current research concerning strength and power training. The subject matter of the conference not only includes information related to training athletes and individuals interested in general fitness, but also benefits of resistance training for elderly and diseased populations. The multi-disciplinary approach of the conference makes it applicable to clinical and health professionals as well as coaches and athletes.

In addition to the presentation of the most current research and information related to the many aspects of strength and power training, the conference also offers an excellent opportunity to exchange information and ideas with colleagues from all over the world.

On behalf of the Norwegian School of Sport Sciences we hope you will enjoy the 8th International Conference on Strength Training.

On behalf of the Local Organizing Committee
Prof. Truls Raastad
Chair, Local Organizing Committee

Contents

Wednesday 24th

Satellite Symposium
09:00 - 12:30
(Auditorium A)
Satellite symposium on the effect of anabolic steroids on muscle mass, performance and health
Fawzi Kadi (Sweden), Ingrid Egner (Norway), Mario Thevis (Germany), Paul Vanberg (Norway)

Registration
12:00 - 14:00
(Main Entrance)

Welcome Session 14:00-14:30 (Aud A)

Invited Symposium 1
14:30 - 16:30
(Auditorium A)
Resistance Training using vascular occlusion (BFRE): Adaptive Mechanisms and usage in Athletic Training and Clinical Rehabilitation
Mathias Wernbom (Sweden), Per Aagaard (Denmark), Todd Manini (USA)

Coffee break

Invited Symposium 2
17:00 - 19:00
(Auditorium A)
Strength training in rehabilitation after injuries
Albert Gollhofer (Germany), Roman Meeusen (Belgium), Ben Rosenblatt (UK)

Welcome Reception
19:30
City Hall

Thursday 25th

Invited Symposium 3
09:00 - 11:00
(Auditorium A)
Strength training and tendons
Jens Bojsen-Møller (Norway), Olivier Seynnes (Norway), Kirsten Albracht (Germany),

Coffee break

Oral Presentation 1
11:30 - 1330
(Auditorium A)

Oral Presentation 2
11:30 - 1330
(Auditorium D)

Lunch

Poster Session 1
14:30 - 16:30
(Sports Hall)

Coffee break

Invited Symposium 4
17:00 - 19:00
(Auditorium A)
The role of strength training for performance in endurance sports
Hans Christer Holmberg (Sweden), Iñigo Mujika (Spain), Keijo Häkkinen (Finland), Bent R Rønnestad (Norway)

Friday 26th

Invited Symposium 5
09:00 - 11:00
(Auditorium A)
Strength training for functional capacity and health in the elderly
Mark Peterson (USA), Michael Kjær (Denmark), Charlotte Suetta (Denmark)

Coffee break

Oral Presentation 3
11:30 - 1330
(Auditorium A)

Oral Presentation 4
11:30 - 1330
(Auditorium D)

Lunch

Poster Session 2
14:30 - 16:30
(Sports Hall)

Coffee break

Invited Symposium 6
17:00 - 19:00
(Auditorium A)
Biomechanics of strength training
Robert U. Newton (Australia), David Behm (Canada), Tron Krosshaug (Norway)

Trip to Holmenkollen
19:00
Transport by bus

Saturday 27th

Invited Symposium 7
09:00 - 11:00
(Auditorium A)
Nutritional factors stimulating hypertrophy and strength
John Hawley (Australia), Stuart Phillips (Canada), Ina Garthe (Norway)

Coffee break

Invited Symposium 8
11:30 - 1330
(Auditorium A)
Recovery after strength trainings sessions
Gøran Paulsen (Norway), Leigh Breen (Canada), Juha Hulmi (Finland), Elisabet Børsheim (USA)

Lunch

Invited Symposium 9
14:30 - 16:30
(Auditorium A)
Strength training in strength and power sports
Stuart Cormack (Australia), Anthony Blazevich (Australia), Alexander Kirketeig (Norway)

Coffee break

Invited Symposium 10
17:00 - 18:00
(Auditorium A)
The endocrine system and strength training adaptions in men and woman
William Kraemer (USA)

Closing Session
18:00 - 19:00
(Auditorium A)
Call for proposals for 2014 conference

Closing Banquet
20:00
Clarion Hotel Royal Christiania

Sunday 28th

Satellite Symposium
09:00 - 13:00
(Auditorium A)
Satellite symposium on cancer patients and effects of strength training on muscle and function
Sophie Fosså (Norway), Rob Newton (Australia), Tormod S. NIlsen (Norway), Simon Lønbro (Denmark), Ryen Larsen/Kristian Overgaard (Denmark)

Invited Speakers Biografies

Albert Gollhofer

Alexander Kierketeig

Anthony Blazevich

Ben Rosenblatt

Bent Rønnestad

Charlotte Suetta

David Behm

Elisabet Børsheim

Gøran Paulsen

Hans Christer Holmberg

Ina Garthe

Inigo Mujika

Jens Bojsen-Møller

John Hawley

Juha Hulmi

Keijo Häkkinen

Kirsten Albracht

Leigh Breen

Mark Peterson

Mathias Wernbom

Michael Kjær

Olivier Seynnes

Per Aagard

Robert Newton

Romain Meeusen

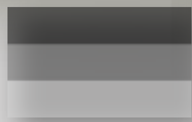
Stuart Cormack

Stuart Phillips

Todd Manini

Tron Krosshaug

William Kraemer



Invited speaker:
Kirsten Albracht
Current position:
Research fellow at the Institute of Biomechanics and Orthopedics of the German Sport University, Cologne
Keynote title:
Strength training in rehabilitation of strength and physical function in elderly patients

Kirsten Albracht received her PhD in Biomechanics at the German Sports University of Cologne. During her PhD she spent a research period at the Institute for Biomedical Research into Human Movement and Health at the Manchester Metropolitan University in United Kingdom. She now holds a position as a research fellow at the Institute of Biomechanics and Orthopedics of the German Sport University Cologne, which is one of Europe's largest and best equipped institutes in the field of sports and clinical biomechanics. Her research has focused on the adaptability and function of mechanical properties of human tendons and their relevance for sport and occupational activities. Her special interest is the musculotendinous interaction within the leg-extensor muscle-tendon units. She is also involved in the German Research Centre of Elite Sport, providing research for health and performance in youth- and elite-sport.

Invited speaker:
David Behm
Current position:
Assosiate Dean, Memorial University of Newfoundland
Keynote title:
The Use of Instability Resistance Training for Health and Performance

Dr. David Behm is the Associate Dean for Graduate Studies and Research in the School of Human Kinetics and Recreation at the Memorial University of Newfoundland. David has an extensive research portfolio with over 100 articles published in peer-reviewed scientific journals that have ben cited more than 3000 times. He has collaborations with researchers on five continents and presents internationally on a regular basis. His research focus has been to investigate neuromuscular responses and adaptations to resistance training, instability, stretching and other activities. David integrates his theoretical work with a background as a competitive athlete and coach in a variety of sport such as football (drafted in Canadian Football League), hockey (Canadian junior hockey), baseball, tennis (provincial champion), squash (provincial champion) and others.

Invited speaker:
Anthony Blazevich
Current position:
Associate Professor in Biomechanics at Edith Cowan University, Australia
Keynote title:
Architectural changes in muscles with strength training applications for performance in power sports

Dr. Anthony Blazevich is an Associate Professor in Biomechanics at Edith Cowan University (Australia). His research focuses on two main themes: 1) understanding of the influence of musculotendinous and neural parameters on movement performance, and 2) examining the effects of physical training interventions (particularly strength and flexibility training) on musculotendinous and nervous system function. In particular, Dr Blazevich has extensively studied muscle hypertrophic and architectural adaptations to training, using ultrasound, MRI and CT imaging for the study of muscle and tendon structure and mechanical properties. He has published 50+ scientific papers, 5 book chapters, 1 textbook (in its second edition) and been invited to speak 48 times to industry and the scientific community, and continues to work with high-performance sporting organisations in Australia, UK, Europe and NZ.

Invited speaker:
Jens Bojsen-Møller
Current position:
Professor in Biomechanics, Department of Physical Performance, Norwegian School of Sport Sciences
Keynote title:
In vivo tendon function

Jens Bojsen-Møller is professor in Biomechanics at the Department of Physical Performance, Norwegian School of Sport Sciences. He is a former olympic athlete and has previolusly worked with the Danish Olympic Sailing team and the Danish federation for elite sports (Team Danmark). His research has focused on the mechanical function of the muscle tendon unit and adaptation to loading. Jens Bojsen-Møller has published more than 30 international peer-reviewed research articles and text-book chapters along with more than 50 conference abstracts at international science meetings.

Invited speaker:
Leigh Breen
Current position:
Research Fellow for The Exercise Metabolism Research Group at McMaster University, UK
Keynote title:
Exercise-induced changes in muscle damage, protein synthesis rate and recovery of function: is there a link

Leigh Breen is a Research Fellow for The Exercise Metabolism Research Group in The Department of Kinesiology at McMaster University. In addition, Leigh is also a Certified Strength and Conditioning Specialist. Leigh graduated from Manchester Metropolitan University with a Bachelors and Master's degree in Exercise Physiology. In 2010 Leigh completed a PhD in Exercise Metabolism and Nutrition at The University of Birmingham.Leigh's research interests focus primarily on the influence of exercise and nutrition, particularly protein and amino acids, on muscle metabolism. Leigh is interested in how these paradigms can be applied to athletes - to help optimize training adaptations, obese adults - to assist in high-quality weight loss, and the elderly - in order to maintain muscle mass, metabolic health and physical mobility with advancing age. Leigh is a regular speaker at international conferences and a peer reviewer for highly respected scientific journals in his research field. In 2011, Leigh was awarded a Young Investigator of the Year award for his research by the European College for Sports Sciences.

Invited speaker:
Elisabet Børsheim
Current position:
Director of the Metabolism Unit, Shriners Hospitals for Children, Dept. of Surgery, University of Texas Medical Branch
Keynote title:
Protein synthesis vs. protein breakdown and exercise per se vs nutritial interventions

Dr. Elisabet Børsheim (PhD) is Director of the Metabolism Unit, Shriners Hospitals for Children, Dept. of Surgery, University of Texas Medical Branch (UTMB). She also has an affiliation with the recently established Dept. of Nutrition and Metabolism, and is an Associate Member in the Preventive Medicine and Community Health Graduate Program at UTMB. Her principal areas of research include the role of free amino acids as regulators of muscle protein synthesis, optimal supplementation for health and performance, the hypermetabolic response to burn injury, and interventions to improve recovery from burn. Elisabet is the Principal Investigator (P.I.) of a National Institutes of Health (NIH) RO1 award to study the effects of amino acid supplementation on regional lipid metabolism in hypertriglyceridemic older people. She is Co-investigator (Co-I.) on several other NIH funded grants, including Co-I. and project P.I. on a P50 grant to study the long term effects of propranolol treatment in burns. She is also P.I. on a five year grant from the Shriners Hospitals for Children on the effect of amino acids and exercise on lipid and protein metabolism in children with burns. She is mentoring several PhDs and Postdocs, and has presented her research in numerous publications, including peer-reviewed journals and book chapters.

Invited speaker:
Stuart Cormack

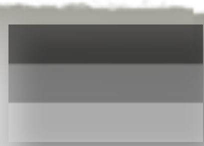
Current position:
Senior lecturer, Australian Catholic University
Keynote title:
Strength training in team sports

Stuart Cormack is currently a Senior Lecturer in Sports Science at the Australian Catholic University in Melbourne and an Adjunct Senior Lecturer at Edith Cowan University in Perth, in addition to providing Sports Science consultancy services to various elite programs. Stuart has spent nearly 20 years working full time in elite sport, including the Australian Football League and the Australian Institute of Sport. Stuart received his PhD from Edith Cowan University and is actively involved in applied research including supervision of multiple post-graduate students. Stuart's work has a focus on team sport and in particular bridging the gap between scientific evidence and practical application. He has published numerous papers in scientific journals, co-authored several book chapters and regularly presents at conferences.

Invited speaker:
Ina Garthe

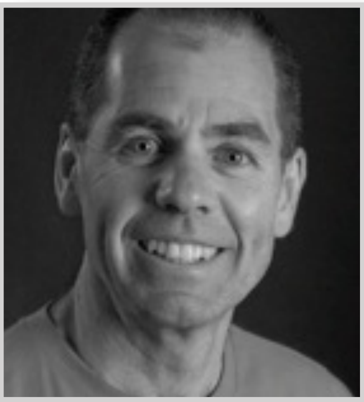
Current position: Head of research and development and daily manager of the Norwegian Olympic Sports Centre, department of Sports nutrition
Keynote title: Changes in body composition and performance in elite athletes during a period with negative energy balance combined with strenght training

Ina Garthe has her PhD from Norwegian School of Sport Sciences, department of Sports Medicine and is the head of research and development and daily manager of the Norwegian Olympic Sports Centre, department of Sports nutrition. She travels with teams and have consultations with elite athletes, mostly within the fields of strength/power training and nutritional strategies, body composition and weight regulation. Her research has focused on athletic nutrition and performance and changes in body composition in elite athletes during strength interventions with negative and positive energy balance, and weight class athletes and nutritional routines. Ina has published several international peer-reviewed research articles and abstracts along with text-book chapters.



Invited speaker:
Albert Gollhofer
Current position:
Professor and Head of the Institute of Sport Science at the University of Freiburg
Keynote title:
Promoting strength and balance training for effective prehab of knee joint injuries

Dr. phil. Albert Gollhofer is currently professor and head of the Institute of Sport Science at the University of Freiburg. He is also in the editorial board of many journals among others Journal of Sports Medicine, European Journal of applied Physiology and European Journal of Sport Science. He is also the former President of the European College of Sport Science.



Invited speaker:
John Hawley
Current position:
Professor at R.M.I.T. University, Melbourne
Keynote title:
Nutritional modulation of exercise training-induced skeletal muscle adaptations (endurance vs. hypertrophy)

John Hawley is currently Head of the Exercise & Nutrition Research Group and Professor of Exercise Metabolism in the Health Innovations Research Institute at R.M.I.T. University, Melbourne, Australia. He has published 200 peer-reviewed scientific manuscripts (PUBMED), written over eighty articles for technical journals and has authored numerous book chapters for exercise biochemistry and sports medicine texts. He currently sits on the Editorial Boards of many international journals including the American Journal of Physiology (Endocrinology and Metabolism); The Journal of Applied Physiology (U.S.A.); The Journal of Sports Sciences (U.K); Medicine & Science in Sports & Exercise (U.S.A.); Sports Medicine (New Zealand; and The International Journal of Sport Nutrition and Exercise Metabolism (U.S.A.). His laboratories research interests include the interaction of exercise and diet on skeletal muscle metabolism; the molecular bases of exercise training adaptation; and the cellular bases underlying exercise-induced improvements in insulin action. He is a consultant for several professional sports teams in Europe and Australia and a regular invited speaker at numerous international conferences every year.

Invited speaker:
Hans Christer Holmberg
Current position:
Professor of Sport Science at the Department of Health Sciences, Mid Sweden University
Keynote title:
Determinates for performance in endurance sports

H-C Holmberg is Professor of Sport Science at the Department of Health Sciences, Mid Sweden University, Sweden. He is also director of the Swedish Winter Sports Research Centre and for Research and Development at the Swedish Olympic Committee; he is a link between research and coaches/athletes in Swedish sport. His research has mainly focused on cross-country and alpine skiing, using an integrative physiology and biomechanical approach, but also includes articles on other sporting disciplines such as cycling or swimming, or topics such as the effect of interval training and hyperoxia on performance. H-C Holmberg has published more than 50 international peer-reviewed research articles and textbook chapters, along with more than 100 conference abstracts in international scientific journals.

Invited speaker:
Juha Hulmi
Current position:
Post Doc, Univeristy of Jyväskylä
Keynote title:
Cell signaling after resistance exercise Mechanical vs metabolic stress (slow vs fast rate of recovery)

Juha Hulmi is a Post-Doctoral researcher in Exercise Physiology at the Department of Biology of Physical Activity, University of Jyväskylä, Finland. His earlier research has focused especially on resistance training adaptation and cell signaling responses. Juha is presently Academy of Finland Post Doc specializing in muscle biology and the regulation of muscle mass in different animal models trying to treat and understand dystrophic muscle. He actively collaborates and works in various muscle and heart tissue hypertrophy and metabolism projects, and also in more applied sports physiology and nutrition studies especially relating to the effects of different types of exercises on signaling in skeletal muscle. Juha spends his free-time working out in the gym, reading bodybuilding literature, writing a skeletal muscle blog and coaching/consulting e.g. personal trainers. Juha has published or submitted for publication ~30 international peer-reviewed research articles and has presented his research findings in various scientific conferences during his short scientific career.

Invited speaker:
Keijo Häkkinen
Current position:
professor and the head in the Department of Biology of Physical Activity at the University of Jyväskylä, Finland
Keynote title:
Neuromuscular adaptations to combined strength and endurance training

Keijo Häkkinen is a professor and the head in the Department of Biology of Physical Activity at the University of Jyväskylä, Finland. He has been qualified for a scientific competence for the academic chairs of the professorship in Biomechanics in 1989, in Exercise Physiology in 1991 and in Science of Sport Coaching and Fitness Testing in 2001 at the University of Jyvaskyla. He has obtained the docentship in Biology of Exercise Training in 1992 in the Medical Faculty at the University of Oulu, Finland. He has over 300 international peer-reviewed research articles, 50 articles in refereed congress proceedings and chapters in books, 10 refereed reviews and books, and over 150 domestic publications. His research interests are broad within the field of biology of physical activity but the major interests focus on neuromuscular and hormonal responses and adaptations during strength training as well as during combined strength and endurance training in men and women at different ages, athletes from various sport events as well as various patient groups. He has given numerous presentations in international scientific congresses and various seminars, and contributed to the organizing process of 25 International Congresses. He is a chairman and a founder member of the International Scientific Committee of International Conference Series on Strength Training.

Invited speaker:
Alexander Kirketeig
Current position:
Coach for the Norwegian Powerlifters
Keynote title:
How do the best powerlifters in the world train?

Alexander Kirketeig B.Sc. is a former Norwegian national powerlifting team member, and has competed in more than 23 international championships from 1996-2009. He is still holding Norwegian records both in Squat and Bench press, in the 90 kg class. Being a member of the Norwegian Powerlifting federation`s board, he has been responsible for education of powerlifting coaches in Norway. Alexander has also been project manager for the Norwegian powerlifting federation, contributing on several studies with Professor Truls Raastad at the Department of Physical Performance, Norwegian School of Sport Sciences. Alexander is now working as a regional manager for the biggest manufacturer of sport supplement in Scandinavia.

Invited speaker:
Michael Kjær
Current position:
Head of Institute of Sports Medicine, Bispebjerg Hospital, Professor in Sports Medicine, Faculty of Health Sciences, University of Copenhagen
Keynote title:
Importance of intramuscular connective tissue for strength and function in elderly

Michael Kjær is MD PhD and specialist in Rheumatology. He is also head of Institute of Sports Medicine, Bispebjerg Hospital, and Professor in Sports Medicine, Faculty of Health Sciences, University of Copenhagen.

Invited speaker:
William Kraemer
Current position:
Professor in the Department of Kinesiology at the University of Conneticut, Storrs, CT
Keynote title:
The endocrine system and strength training adaptations in men and women

Dr. William J. Kraemer is a full professor in the Department of Kinesiology in the Neag School of Education working in the Human Performance Laboratory at the University of Connecticut, Storrs, CT. He also holds and joint appointments as a full professor in the Department of Physiology and Neurobiology and as a Professor of Medicine at the UConn Health School of Medicine. Dr. Kraemer is a Fellow in the American College of Sports Medicine and the National Strength and Conditioning Association. He has authored and co-authored over 400 peer reviewed manuscripts in the scientific literature related to sports medicine, exercise endocrinology, and sport science. In addition, he has authored or co-authored 10 books in the areas of strength training and physiology of exercise, his recent book Exercise Physiology: Integrating Theory and Application was just published in 2012. He was awarded the University of Connecticut's Research Medal in 2005 and recently in 2009 the UConn Alumni Association's "Research Excellence Award in Sciences" for UConn faculty.

Invited speaker:
Tron Krosshaug
Current position:
Associate professor at the Oslo Sports Trauma Research Center and the Department of Sports Medicine, Norwegian School of Sport Sciences
Keynote title:
Revealing “secrets” of strength training exercises with kinetic analyses

Tron Krosshaug, PhD is associate professor at the Oslo Sports Trauma Research Center and the Department of Sports Medicine at the Norwegian School of Sport Sciences and. His main research area is sports injury prevention, with a primary focus on video analysis and biomechanical analysis of serious knee injuries in various sports. He has published 20 papers in highly ranked international peer-reviewed journals and written several book chapters in international expert books on sports injury research and prevention. Krosshaug is also a lecturer in biomechanics and functional anatomy, strength, endurance and flexibility training science nationally and internationally. In addition he is involved in innovation projects where the aims are to develop animations to visualize technique, muscle activation and biomechanical principles in base strength exercises. Tron is of the opinion that life quality increases with frequent bench pressing.

Invited speaker:
Todd Manini
Current position:
Department of Aging and Geriatric Research, University of Florida
Keynote title:
Viability of BFR exercise for rehabilitation

A native of Wintersville, Ohio, Dr. Manini attended Ohio University in Athens, OH where he graduated with honors in Biology, Exercise Science, and Biochemistry. He received his M.S. and Ph.D. as well as a Certificate of Advanced Studies in Gerontology from Syracuse University. He completed a post-doctoral fellowship at the Laboratory of Epidemiology, Demography and Biometry at the National Institute on Aging at the National Institutes of Health in Bethesda, MD. He now resides at the University of Florida in the Department of Aging and Geriatric Research. Dr. Manini received funding from the National Institute on Aging, American College of Sports Medicine/F.M. Kirby Foundation and McKnight Foundation in support of his research on interventions to preserve physical and cognitive function in late-life. He is a fellow of the American College of Sports Medicine and his research is focused on testing new interventions to combat muscle weakness in older persons.

Invited speaker:
Romain Meeusen
Current position:
Head of the department of Human Physiology at the Vrije Universiteit, Brussel
Keynote title:
Strength training – is the brain involved?

Prof Dr Romain Meeusen, (PhD) is head of the department of Human Physiology at the Vrije Universiteit Brussel. His research interest is focussed on “Exercise and the Brain in Health & Disease” exploring the influence of neurotransmitters on human performance, training. His department has a special interest in the ‘brain aspects’ of the Overtraining Syndrome. Romain is the first author on the Consensus statement on ‘Overtraining’ from the European College of Sports Science (ECSS) Recent work is on Thermoregulation, Neurogenesis, Cognition in health & disease. He teaches on exercise physiology, training & coaching and sports physiotherapy. Romain published over 380 articles and book chapters in peer-reviewed journals, 18 books on sport physiotherapy, and gave lectures at more than 730 national and international conferences. He is President of the Belgian Society of Kinesiology, and past President of the Belgian Federation of Sports Physiotherapy. He is Board member of the ECSS, and Board member of the American College of Sports Medicine (ACSM). In 2009 he received the Belgian ‘Francqui Chair’ at the Université Libre de Bruxelles on ‘Exercise and the Brain’. He is also holder of two named lecturing chairs at the Vrije Universiteit Brussel. He is director of the Human Performance lab of the Vrije Universiteit Brussel, where he works with several top athletes, and is scientific advisor of the ‘Lotto Cycling Institute’ (Lotto-Belisol professional cycling team).

Invited speaker:
Iñigo Mujika
Current position:
Director of Physiology and Training at USP Araba Sport Clinic, Professor at the University of the Basque Country
Keynote title:
Strength training in endurance sports: pros and cons

Iñigo Mujika earned Ph.D.s in Biology of Muscular Exercise (University of Saint-Etienne, France) and Physical Activity and Sport Sciences (University of The Basque Country). He is a Level III Swimming and Triathlon Coach and coaches World Class triathletes. His main research interests in applied sport science include training methods,recovery, tapering, detraining and overtraining. Iñigo has performed extensive research on the physiological aspects of sports performance in professional cycling, swimming, running, rowing, tennis, football and water polo. He received research fellowships in Australia, France and South Africa, published over 80 articles in peer reviewed journals, three books and 25 book chapters, and has given over 190 lectures in international conferences and meetings. Iñigo was Senior Physiologist at the Australian Institute of Sport in 2003 and 2004. In 2005 he was physiologist and trainer for Euskaltel Euskadi professional cycling team, and between 2006 and 2008 he was Head of Research and Development at Athletic Club Bilbao professional football club. He is now Director of Physiology and Training at USP Araba Sport Clinic, Physiology Consultant of the Spanish Swimming Federation, Associate Editor for the International Journal of Sports Physiology and Performance, and Associate Professor at the University of the Basque Country.

Invited speaker:
Robert Newton
Current position:
Professor, Edith Cowan University
Keynote title:
Combined strength and power training for optimal performance gains: A biomechanical approach

Professor Robert Newton is the Foundation Professor in Exercise and Sports Science at Edith Cowan University, Perth, Western Australia. Professor Newton is an Accredited Exercise Physiologist, Certified Strength and Conditioning Specialist with Distinction with the NSCA, Fellow of Exercise and Sports Science Australia and Fellow of the National Strength and Conditioning Association (NSCA). In 2004 he was awarded Outstanding Sports Scientist of the Year by the NSCA. He has published over 200 refereed scientific articles, two books, 14 book chapters and has a current h-Index of 51 with his work being cited over 9,821 times. As of 2012 his research had attracted over $12Million in competitive research funding. Professor Newton has an extensive track record of research and consultancy in the assessment and development of neuromuscular performance in particular maximal strength and power. He has been a consultant to many professional teams and sporting organisations including Chicago Bulls, New Jersey Nets, Indianapolis Colts, England Rugby, Manchester United, English and Australian Institutes of Sport. In 2012 Professor Newton was appointed to the Advisory Board of Nike SPARQ.

Invited speaker:
Gøran Paulsen
Current position:
Postdoc at the Department of Physical Performance, Norwegian School of Sport Sciences. Adjunct Associated Professor at The Norwegian Defence University College
Keynote title: General intro and factors affecting rate of recovery and training frequency

Gøran Paulsen has a postdoc position at the Department of Physical Performance, Norwegian School of Sport Sciences. He holds also a position as Adjunct Associated Professor at The Norwegian Defence University College. His research has focused on recovery processes after intensive exercise sessions (e.g. eccentric exercise), as well as training-induced adaptive change in muscle morphology, muscle architecture and muscle function. Gøran's postdoc project deals with the effect of antioxidant supplementation on recovery from and adaptation to both endurance and strength training. Gøran Paulsen has authored more than 20 international peer-reviewed research articles and text-book chapters, along with about 50 abstracts in national and international scientific conferences. He has been an invited speaker at the European College of Sport Science Congress and the American College of Sports Medicine Congress.

Invited speaker:
Mark Peterson
Current position:
Assistant Research Professor, University of Michigan
Keynote title:
Changes in strength and functional capacity with aging: How do we implement strength training in elderly and which improvements can we expect?

Dr. Mark Peterson is an Assistant Research Professor at the University of Michigan Medical School, Department of Physical Medicine and Rehabilitation. Mark earned a B.S. in Kinesiology from the University of Michigan, and an M.S and Ph.D. in Physical activity, Nutrition and Wellness from Arizona State University. He is currently pursuing an additional M.S. in Clinical Research Design and Biostatistics through University of Michigan's School of Public Health. Mark's early research endeavors included investigating performance enhancement strategies for a broad range of athletic and tactical populations. However, during his doctoral and post-doctoral training he became increasingly drawn to the fact that various elements of his work had wide implication for public health. Mark's current research agenda is focused on obesity and inflammation, healthy aging, and the cellular mechanisms of muscle wasting and metabolic health in motor disabilities. Mark is a recent recipient of a 5-year National Institutes of Health (NIH) KO1 award, to study the effects of exercise to reduce secondary muscle pathology in adults with cerebral palsy. He is a certified strength and conditioning specialist with distinction, through the NSCA, as well as an Associate Editor for the Journal of Strength and Conditioning Research.

Invited speaker:
Stuart Phillips
Current position:
Professor, Department of Kinesiology McMaster University, Hamilton, ON
Keynote title:
Protein supplementation and hypertrophy: An update

Stuart Phillips has B.Sc. and M.Sc. degrees from McMaster. He graduated with a Ph.D. from the University of Waterloo in Human Physiology in 1995. He returned to McMaster in 1997 to assume a faculty position and is now a Professor in the Department of Kinesiology and an Adjunct Professor in the School of Medicine at McMaster University. Stuart is a fellow of the American College of Sports Medicine (ACSM) and the American College of Nutrition (ACN). His research is focused on the impact of nutrition and exercise on human skeletal muscle protein turnover. As well he is keenly interested in diet and exercise-induced changes in body composition. His research has been continually funded for 16 years from sources such as the Canadian Institutes for Health Research, the National Science and Engineering Council of Canada, the Canadian Institutes for Health Research, The Canadian Foundation for Innovation, The US Department of Agriculture, and various industry partners. Dr. Phillips was the recipient of a New Investigator award recipient from the Canadian Institutes for Health Research and of the Ontario Premier's Research Excellence Award. An enthusiastic and energetic group of graduate students are the true heart of Dr. Phillips' more than 150 publications, 100 public scientific presentations, and continuing enthusiasm for science and research.

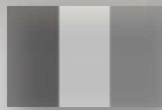
Invited speaker:
Ben Rosenblatt
Current position:
Senior Rehabilitation Scientist, The British Olympic Medical Institute and English Institute of Sport
Keynote title:
The effect of low load blood flow restricted resistance training in rehabilitation of elite athletes

Ben Rosenblatt is the Senior Rehabilitation Scientist at the Intensive Rehabilitation Unit of the British Olympic Medical Institute and English Institute of Sport. The role of the IRU is to accelerate the rehabilitation of injured Olympic athletes. Ben is responsible for providing strength and conditioning coaching to injured Olympic athletes, providing objective evidence to support the process of clinical reasoning and developing innovative solutions to rehabilitation problems. Ben is currently completing his PhD in biomechanics and S&C (Cardiff School of Sport), coaches several members of the British Olympic Judo team and is an honorary lecturer at University College London. Previously Ben led the Sports Science and Fitness department at Birmingham City FC, worked as an S&C coach at the Olympic Medical Institute and has worked in college and university sport in the USA and UK.

Invited speaker:
Bent Rønnestad
Current position:
Associate Professor in Exercise Physiology at the Section for Sports Science, Lillehammer University College
Keynote title:
Effect of strength training on cycling performance

Bent R. Rønnestad is Associate Professor in Exercise Physiology at the Section for Sports Science, Lillehammer University College, Norway. Major research interests of his research group includes training for strength and power, optimizing strength and endurance training for sports performance.

Invited speaker:
Olivier Seynnes
Current position:
Associate Professor at the Department of Physical Performance, Norwegian School of Sport Sciences
Keynote title:
Tendon adaptation in response to chronic loading/ strength training



Olivier Seynnes is an Associate Professor at the Department of Physical Performance, Norwegian School of Sport Sciences. His research covers the fields of neuromuscular and tendinous adaptations to exercise, disuse and ageing. His current work focuses on methodological and theoretical aspects of tendon testing and on morphological and mechanical plasticity of tendons with resistance training. Olivier Seynnes is a member of the Nordic Muscle Tendon Network and an Advisory Editor for the European Journal of Physiology. He has published over 30 peer-reviewed research articles, two book chapters and a book, and has contributed to more than 40 international conferences.

Invited speaker:
Charlotte Suetta
Current position:
Doctor of Medicine, Denmark
Keynote title:
Strength training in rehabilitation of strength and physical function in elderly patients

Charlotte Suetta is an MD and in her research she has been focusing on changes in muscle function with aging, inactivity and physical training. More specifically, changes in muscle morphology, neuromuscular function and muscle mechanical properties with disuse related inactivity in elderly patients as well as effects of different rehabilitation regimes in elderly patients after hip-surgery has been studied. Lately, the main focus has been on the modulation in cellular signaling pathways involved in the initiation and temporal development of human disuse muscle atrophy, and specifically examining if aging affects the molecular regulation of human disuse related muscle loss and the sub-sequent ability to regain muscle mass.

Invited speaker:
Mathias Wernbom
Current position:
Researcher at the Lundberg Laboratory for Orthopaedic Research, University of Gothenburg, Sweden
Keynote title:
Cellular and molecular hypertrophy signaling BFR

Mathias Wernbom, PhD MSc PT, is a researcher at the Lundberg Laboratory for Orthopaedic Research, University of Gothenburg, Sweden. He obtained his PhD degree from the Norwegian School of Sport Sciences, Oslo, Norway. His past and current research interests are exercise and muscle physiology in general, and the physiology of muscle growth caused by strength training and blood flow restricted resistance exercise (BFRRE) in particular. In his research, he has collaborated with groups at the Norwegian School of Sport Sciences, the University of Southern Denmark and the University of Jyväskylä, Finland. Mathias has 20+ years experience of strength training as a trainer, physical therapist and instructor. In his spare time, he enjoys working out at the gym, listening to and playing (guitar) various types of music, and spending time by the sea.

Invited speaker:
Per Aagaard
Current position:
Professor in Biomechanics at University of Southern Denmark, Odense
Keynote title:
Hyperactivation of myogenic satellite cells with blood flow restricted exercise

Per Aagaard is professor in Biomechanics at the Institute of Sports Science and Clinical Biomechanics at University of Southern Denmark, Odense. He has previously worked for the Danish Elite Sports Organisation (Team Danmark), providing physiological research, testing and supervision of Danish elite athletes within the fields of strength/power training and neuromuscular training adaptation. His research covers the adaptive change in neuromuscular function, and muscle architecture & morphology induced by training and detraining/inactivity, including aging and immobilization. Other research areas focus on the role of antagonist muscle coactivation, spinal motor function during walking, running and resistance training, and in vivo muscle-aponeurosis-tendon function, including ACL injury, tendon overuse injury, tendinopathy, and athletic performance. He has published 160+ peer-reviewed research articles and book chapters in international scientific journals and text books, and serves as Editorial Board member for the Medicine and Science in Sports and Exercise, Exercise and Sports Science Reviews, Scandinavian Journal of Medicine and Science in Sports, Journal of Strength & Conditioning Research.

INVITED SYMPOSIA

Oct. 24th -27th
(Auditorium A)

Wednesday the 24th of October

14:30 - 16:30

SYMPOSIUM 1: ***Resistance Training using vascular occlusion (BFRE): Adaptive Mechanisms and usage in Athletic Training and Clinical Rehabilitation***

Chair: Per Aagaard

1. Mathias Wernbom: *Cellular and molecular hypertrophy signaling BFR*
2. Per Aagaard: *Hyperactivation of satellite cells with BFRE*
3. Todd Manini: *Viability of BFR exercise for rehabilitation*

17:00 - 19:00

SYMPOSIUM 2: ***Strength training in rehabilitation after injuries***

Chair: Albert Gollhofer

1. Albert Gollhofer: *Promoting strength and Balance Training for effective Prehab of Knee Joint Injuries*
2. Romain Meeusen: *Strength training – is the brain involved?*
3. Ben Rosenblatt: *The effect of low load blood flow restricted resistance training in rehabilitation of elite athletes*

Thursday the 25th of October

09:00 - 11:00

SYMPOSIUM 3: *Strength training and tendons*

Chair: Jens Bojsen-Møller

1. Jens Bojsen-Møller: I*n vivo tendon function*
2. Olivier Seynnes: *Tendon adaptation in response to chronic loading/strength training*
3. Kirsten Albracht: *Tendon properties in relation to optimal sports performance*

17:00 - 19:00

SYMPOSIUM 4: ***The role of strength training for performance in endurance sports***

Chair: Jostein Hallén

1. Hans Christer Holmberg: *Determinates for performance in endurance sports*
2. Iñigo Mujika: *Strength training in endurance sports, pro and cons*
3. Keijo Häkkinen: *Neuromuscular adaptations to combined strength and endurance training*
4. Bent R Rønnestad: *Effect of strength training on cycling performance*

Friday the 26th of October

09:00 - 11:00

SYMPOSIUM 5: ***Strength training for functional capacity and health in the elderly***

Chair: Keijo Häkkinen

1. Mark Peterson: *Changes in strength and functional capacity with aging: How do we implement strength training in elderly and which improvements can we expect?*
2. Michael Kjær: *Importance of intramuscular connective tissue for strength and function in elderly*
3. Charlotte Suetta: *Strength training in rehabilitation of strength and physical function in elderly patients*

17:00 - 19:00

SYMPOSIUM 6: ***Biomechanics of strength training***

Chair: Tron Krosshaug

1. Robert U. Newton: *Combined strength and power training for optimal performance gains: A biomechanical approach*
2. David Behm: *The Use of Instability Resistance Training for Health and Performance*
3. Tron Krosshaug: *Revealing "secrets" of strength training exercises with kinetic analyses*

Saturday the 27th of October

09:00 - 11:00

SYMPOSIUM 7: ***Nutritional factors stimulating hypertrophy and strength***

Chair: Ina Garthe

1. John Hawley: *Nutritional modulation of exercise training-induced skeletal muscle adaptations (endurance vs. hypertrophy)*
2. Stuart Phillips: *Protein supplementation and hypertrophy: An update*
3. Ina Garthe: *Nutritional interventions effective in keeping lean mass during caloric restrictions*

11:30 - 13:30

SYMPOSIUM 8: ***Recovery after strength training sessions***

Chair: Gøran Paulsen

1. Gøran Paulsen: *General intro and factors affecting rate of recovery and training frequency*
2. Leigh Breen: *Recovery of muscle function in relation to protein synthesis; relevance for training frequency*
3. Juha Hulmi: *Cell signaling after resistance exercise Mechanical vs metabolic stress (slow vs fast rate of recovery)*
4. Elisabet Børsheim: *Protein synthesis vs. protein breakdown and exercise per se vs nutritial interventions*

14:30 - 16:30

SYMPOSIUM 9: ***Strength training in strength and power sports***

Chair: Dietmar Schmidtbleicher

1. Stuart Cormack: *Strength training in team sports*
2. Anthony Blazevich: *Architectural changes in muscles with strength training – applications for performance in power sports*
3. Alexander Kirketeig: *How do the best powerlifters in the world train?*

17:00 - 18:00

SYMPOSIUM 10: ***The endocrine system and strength training adaptations in men and women***

Chair: Truls Raastad

1. William Kraemer: *The endocrine system and strength training adaptations in men and women*

BLOOD FLOW RESTRICTED RESISTANCE EXERCISE: POSSIBLE STIMULI AND SIGNALING PATHWAYS

Mathias Wernbom[1,2]

[1]Lundberg Laboratory for Human Muscle Function, University of Gothenburg, Sweden.[2]Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway.

INTRODUCTION

Low load resistance exercise (~20-50% of 1 RM) in combination with blood-flow restriction (BFR) by the use of pressure cuffs has repeatedly been shown to induce muscle hypertrophy in untrained individuals (33). Resistance exercise with BFR (BFRRE), often also referred to as strength training with vascular occlusion or simply "occlusion training", can also induce gains in muscle strength and size in the elderly (15) as well as in trained athletes (30), and may counteract disuse muscle atrophy in healthy individuals (5) and in patients recovering after anterior cruciate ligament surgery (23).

Because of the many potential applications of BFRRE it is of great interest, both from a practical standpoint and from a basic research point of view, to try to clarify how occlusion training induces gains in strength and muscle size.

PHYSIOLOGY OF BFRRE – POSSIBLE STIMULI FOR HYPERTROPHY

Motor unit recruitment

It is generally held that with strength training, hypertrophy occurs primarily in the fibers which have been recruited during the exercise, and that hypertrophy is typically greater in type II (fast twitch) fibers than in type I (slow twitch) fibers (17).

Low-load BFRRE performed close to torque failure can result in high levels of muscle activity, as judged by electromyography (EMG). For example, Takarada et al. (29) demonstrated that the EMG of the biceps brachii during low-intensity resistance exercise (40% of 1RM) combined with partial occlusion of the muscle blood flow was almost equal to that observed during conventional heavy resistance exercise (80% of 1RM). In line with this finding, Wernbom et al. (34) showed that during BFRRE at 30% of 1RM in the knee extension exercise, EMG of the quadriceps during the concentric phase reached values close to 100% of MVC during sets near the point of task failure. Collectively, these and other EMG studies indicate that muscle activity during fatiguing BFRRE can be sufficiently high for recruitment of the majority of both type I and type II fibers to occur.

Recruitment of type II fibers during low-load BFRRE has been confirmed by measurements of phosphocreatine in muscle samples (18) and by ^{31}phosphorus-magnetic resonance spectroscopy (28). Interestingly, Takada et al. (28) reported that individuals who recruited type II fibers with BFRRE tended to gain more in muscle cross-sectional area (CSA) with four weeks of BFRRE than those who did not display recruitment of type II fibers (~6% vs ~4% increase in CSA). Thus, the available evidence strongly supports the importance of a high degree of motor unit recruitment.

Cell swelling

It has been proposed that cell swelling is an anabolic and anti-catabolic stimulus for skeletal muscle, and that this is one of the mechanisms by which BFR exercise induces muscle growth (2, 19). To date, however, there is insufficient evidence to conclude that cell swelling *per se* acts as a hypertrophic stimuli in skeletal muscle, as some studies have showed a positive effect of cell swelling on hypertrophy signaling (6, 20) and protein synthesis (6), while others have failed to demonstrate such effects, although protein breakdown was slightly decreased (8).

Metabolic and ischemic stresses

A recent study (28) reported strong correlations between indices of BFRRE-induced metabolic stress such as inorganic phosphate (Pi), pH, diprotonated phosphate (H_2PO4^-) and the resulting hypertrophy. The strongest correlation was observed between acute increases in Pi and muscle area gains.

Interestingly, Takada et al. (28) argued that metabolic stress was more important than type II fiber recruitment, based on the strong correlations between indices of metabolic stress and hypertrophy. However, it could also be argued that increases in Pi to a large extent reflect recruitment and the overall level of work, and that mechanical parameters such as peak tension, stretch and time under tension are the real variables at work. Hence, it is not entirely clear if metabolic stress *per se* is a factor which stimulates muscle growth, or to what extent it may interact with the effects of other stimuli (e.g., mechanical tension, stretch, cell swelling).

Closely related to metabolic stress are the stresses caused by ischemia and reperfusion. Ischemic conditions may of course amplify exercise-induced changes in Pi, pH, H_2PO4^-, etc. In addition, ischemia and reperfusion are both known to cause increases in reactive oxygen and nitrogen species (RONS), which may have both beneficial (e.g. hypertrophy) and detrimental effects (e.g, atrophy) on skeletal muscle fibers. However, there is currently limited information on the effects of BFRRE on RONS production.

Muscle damage

Up until recently, it was believed that BFRRE did not induce muscle damage. However, delayed onset muscle soreness (DOMS) after low-load BFRRE was reported already 6 years ago by Wernbom et al. (32) and subsequently by Umbel et al. (31) and in other studies by Wernbom et al. (34, 35). Furthermore, both Umbel et al. (31) and Wernbom et al. (35) reported additional signs suggesting muscle damage (torque decrements, muscle swelling and sarcolemmal permeability) after BFRRE. Finally, a recent case study reported rhabdomyolysis after a single bout of fatiguing low-load BFRRE (14). Thus, it appears that BFFRE can induce muscle damage under some circumstances.

The underlying basis of muscle damage with BFRRE is unknown, but may be related to temporarily low local energy levels in the muscle fiber, which together with the muscle activity lead to increased accumulation of calcium (Ca2+), which in turn activates the damage pathways (9).

It is the hypothesis of the present author that mild muscle damage may be an important factor behind the training effects of BFRRE. Furthermore, it is hypothesized that metabolic stress, muscle swelling and mechanical tension (contractions and/or stretch) interact to cause damage with BFFRE. The muscle damage may in turn stimulate relatively long lasting muscle fiber swelling and signaling, and contribute to growth factor release and production, as well as activation and proliferation of satellite cells (SC) and fusion of SC-derived myoblasts with myofibers (myonuclear addition).

PATHWAYS AND MECHANISMS OF MUSCLE HYPERTROPHY WITH BFRRE

The mammalian/mechanistic Target of Rapamycin (mTOR) pathway

A central protein kinase in the regulation of muscle growth is the mechanistic target of rapamycin (mTOR). It exists in complexes with other proteins, and to date two mTOR complexes have been discovered, mTOR complex 1 (mTORC1) and 2 (mTORC2). The mTORC1 appears to be the most important for protein synthesis regulation via downstream effectors such as p70S6K (also called S6K), 4E-BP´s and eEF2 (3, 24). Numerous studies to date have indicated that activation of mTOR is necessary for the induction of protein synthesis and hypertrophy in skeletal muscle (3, 7, 12, 13).

An acute bout of BFRRE has been shown to cause increased mTOR-p70S6K signaling at 1-3 hours post-exercise (10, 11, 37). Furthermore, preliminary data suggests that the increased mTOR-p70S6K signaling may last as long as 24 hours post-exercise (37). This may in part explain why even low-frequency (2-3 sessions per week) BFRRE can be successful in inducing muscle hypertrophy.

The stimuli which activate increased mTOR signaling with BFRRE are currently unknown, but upstream signaling may include Akt/PKB and/or Akt/PKB-independent pathways such as the mitogen activated protein kinases (MAPKs).

The MAPK pathways

The MAPK pathways include the extracellular regulated kinases (ERK) 1/2, the p38MAPK (p38) and the the c-jun n-terminal kinases (JNK) families. Each of these families consists of several members, and many of these are expressed in skeletal muscle. Importantly, ERK1/2, p38MAPKs and JNKs have all been shown to be activated by heavy resistance exercise (4, 16). Moreover, all three major MAPK families have been shown to be involved in mTOR signaling in various cell types, and have been suggested to be involved in mechanically induced muscle growth. The MAPKs and their downstream effectors may also impact on protein synthesis independently of mTOR, via for example several important molecules such as p70S6K, rpS6, MNKs and GSK3beta (Figure 1).

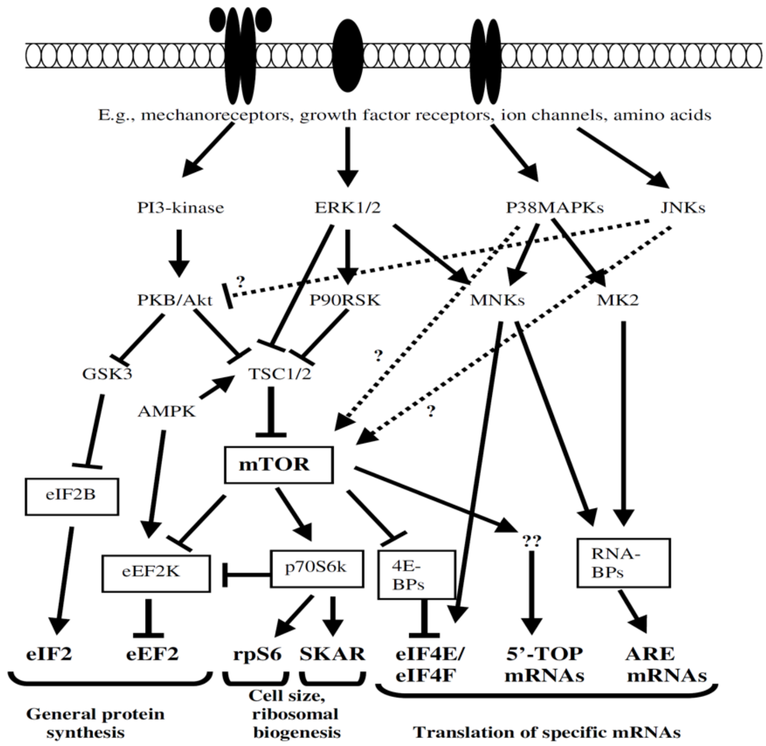


Figure 1. Some of the pathways regulating muscle protein synthesis. Modified from Proud, 2007.

However, all three major MAPKs have also been implicated in muscle atrophy in response to various atrophic stimuli. These seemingly conflicting findings may in part be explained by differences in the duration and/or amplitude of MAPK signaling, and/or the isoforms of MAPKs involved.

Increased phosphorylation of ERK1/2 has been demonstrated early after acute BFRRE (10). Regarding the response of p38 to BFFRE, there is currently little information available. We have observed increased phosphorylation of p38 at 1 hour after acute BFRRE with multiple sets to failure (37). To the best of the authors' knowledge, no study to date has investigated the response of JNKs to BFRRE.

Proteolytic pathways

In addition to increased protein synthesis, muscle hypertrophy may also occur if muscle protein breakdown (proteolysis) is decreased. Some of the proteolytic pathways include the ubiquitin-proteasome system, the lysosome/autophagy system, the calpains and the caspases (27).

Two important muscle-specific ubiquitin ligases, atrogin-1/MAFbx and MuRF1, are responsible for much of the increased protein breakdown through the ubiquitin-proteasome system. Atrogin-1 and MuRF1 are controlled by the FOXO family of transcription factors (FOXO1, FOXO3a, and FOXO4) and the NF-kappaB transcription factor (25, 27). Overexpression of FOXO1 or FOXO3a has each been shown to be sufficient for muscle atrophy to occur (27).

Interestingly, inhibition of FOXO transcriptional activity results in muscle hypertrophy, and this appears to be at least in part dependent on increases in muscle protein synthesis mediated by the mTOR pathway (26). Thus, the hypertrophic effects of inhibiting FOXOs likely involve both decreased breakdown and increased protein synthesis.

Recently, BFRRE was shown to result in decreased mRNA of FOXO3a, Atrogin-1 and MuRF1 at 8 hours post-exercise (21). It may thus be speculated that decreased contents of FOXO3a and ubiquitin ligases are part of the mechanisms behind the prolonged mTOR signaling observed after acute BFRRE (37).

Satellite cell activation and myonuclear addition

A recent study by Nielsen et al. (22) demonstrated marked increases in SCs and in myonuclei after a short-term period of high frequency BFRRE. Interestingly, both the numbers of SCs and myonuclei were correlated with muscle fiber area both before and after the training period. For further details, see Per Aagaards presentation.

In addition, using a similar BFRRE protocol, we have shown elevated numbers of SCs already after a single bout of BFRRE (Wernbom et al., unpublished). The mechanisms responsible for these elevations may include damage-induced pathways, ROS/RNS, growth factor release, etc (see above).

CONCLUSION

Despite the low loads, the stimuli and the signaling pathways involved in BFRRE-induced muscle hypertrophy appear to be largely similar to those involved in heavy resistance exercise, i.e., high levels of muscle activity, some degree of muscle damage/remodeling, activation of pathways leading to increased protein synthesis and decreased breakdown, and satellite cell mediated myonuclear addition.

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HYPERACTIVATION OF MYOGENIC SATELLITE CELLS WITH BLOOD FLOW RESTRICTED EXERCISE

Per Aagaard

Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark

INTRODUCTION

Blood flow restricted exercise

Blood flow restricted exercise at low-to-moderate loading intensity (20–50% 1RM) using concurrent blood flow restriction (BFRE) has gained increasing attention in both the scientific and applied fields (Manini & Clarck 2009, Wernbom et al. 2008). The growing popularity resides on observations that skeletal muscle mass and maximal muscle strength can be increased to a similar or greater extent with BFRE (Wernbom et al. 2008) compared to conventional heavy-resistance strength training (Aagaard et al. 2001). Further, BFRE seems to result in amplified hypertrophy responses and strength gains compared to exercise using identical loads and volume without vascular occlusion (Abe et al. 2006, Holm et al. 2008) although a potential hypertrophic role of low-intensity resistance training may also exist per se (Mitchell et al. 2012). Yet, the specific mechanisms responsible for the adaptive change in muscle morphology with BFRE remain largely unknown. Myofibrillar protein synthesis is increased following acute bouts of BFRE, along with an upregulated activity in the AKT/mTOR pathway (Fujita et al. 2007, Fry et al. 2010). In addition, a reduced expression of proteolysis-related genes (FOXO3a, Atrogin, MuRF-1) and myostatin, a negative regulator of muscle mass has been observed after acute BFRE (Manini et al. 2011, Laurentino et al. 2012).

Myogenic satellite cells

Satellite cells (SCs) are undifferentiated myogenic precursor cells with the ability to re-enter the cell cycle to generate new muscle fibers and/or to provide new myonuclei to existing muscle fibers during postnatal growth (Kadi et al. 2005, Hawke & Garry 2001, Boldrin et al. 2010). In resting skeletal muscle quiescent SCs are located between the basal lamina and sarcolemma of the myofiber (Kadi et al. 2005, Pallafacchina et al. 2012). Resistance training appears to induce a renewal of SCs in human skeletal muscle of both old and young individuals (Zammit et al. 2006, Mackey et al. 2007, Kadi & Ponsot 2010) in a dose-dependant manner (Hanssen et al. 2012). Activation and proliferation of myogenic SCs are associated with accelerated and amplified hypertrophy responses following resistance training (Petrella et al. 2008, Olsen et al. 2006) and the amount of myonuclei in the myofiber has been proposed to impose a ceiling effect on the magnitude of myofiber hypertrophy (Kadi et al. 2004, Petrella et al. 2008). Exercise induced myonuclear addition occurs mainly in the presence of highly marked myofiber hypertrophy (Kadi & Thornell 2000, Kadi et al. 2004, Olsen et al. 2006, Petrella et al. 2008, Mackey et al. 2010). This suggests that SC activation play an essential role in conditions of amplified muscle protein synthesis by providing increased transcriptional capacity to the muscle cell. However, until very recently the effect of BFRE on myogenic SC activation and myonuclear addition has remained unknown.

Effects of BFRE on contractile muscle function

Significant increases in maximal muscle strength (MVC) and power have been reported following BFRE using low-to-moderate training loads, despite relatively short periods of training (4-6 wks) (i.e. Takarada et al. 2002, Kubo et al. 2006; for review see Wernbom et al. 2008). Notably, the adaptive effect of BFRE on contractile muscle function (MVC, power) is comparable to that achieved by 12-16 wks of conventional high-volume heavy-resistance strength training (Wernbom et al. 2008). However, the effect of BFRE on rapid force capacity (rate of force development: RFD) has remained largely unexplored, while only very recently addressed (Nielsen et al, ICST 2012; discussed below).

Effects of BFRE on myofiber size

Substantial gains myofiber size and whole muscle CSA have been demonstrated following BFRE using low loading intensities (Abe et al. 2006, Ohta et al. 2003, Kubo et al. 2006, Takadara et al. 2002). In contrast, low-resistance training without blood flow occlusion typically results in no (Abe et al. 2006, Mackey et al. 2010) or only minor gains (<5%) (Holm et al. 2008) in myofiber size, although this notion recently has been disputed (Mitchell et al. 2012). Interestingly, the proliferation of myogenic SCs and formation of new myonuclei with BFRE seem to explain at least in part the very large gains in myofiber size that may be observed with this type of training (discussed below).

Effects of BFRE on myogenic satellite cells and myonuclei number

We recently investigated the involvement of myogenic SC proliferation and myonuclear addition in response to BFRE (Nielsen et al. 2012). Evidence of SC proliferation and myonuclear addition were observed following 3 weeks of BFRE, accompanied by substantial gains in myofiber size (Nielsen et al. 2012) (Fig.1). Density and number of Pax-7+ SCs increased 1-2 fold (+100-200%) after 19 days of BFRE (Fig.2), thus markedly exceeding the 20-40% gain in SC number typically seen in response to months of conventional resistance training (Kadi et al. 2005, Olsen et al. 2006, Mackey et al. 2007). SC number and density increased to a similar extent in type I and II myofibers (Nielsen et al. 2012) (Fig.2) in contrast to the greater SC response in type II vs. type I fibers normally observed following prolonged heavy-load resistance training (Verdijk et al. 2009). In addition, myonuclei number increased significantly (+22-33%) with BFRE, while myonuclei domain (myofiber size/number of nuclei) remained constant (~1800-2100 μm2) although demonstrating a slight albeit transient decrease at day 8 of training (Nielsen et al. 2012).

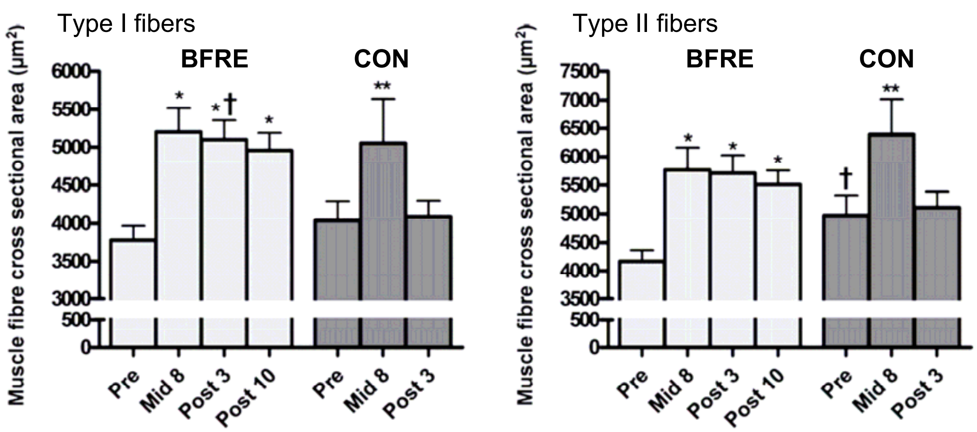

Fig.1 Myofiber cross-sectional area (CSA) measured pre and post 19 days of low-resistance (20%-1RM) blood flow restricted exercise (BFRE) or work/load matched exercise without blood flow occlusion (CON) in type I (left panel) and type II fibers (right panel). Changes relative to pre: * $p<0.001$, ** $p<0.01$, between group difference: † $p<0.05$. Adapted from Nielsen et al. 2012.

Implications for myofiber growth

The rise in SC activity induced by BFRE (cf. Fig.2) were accompanied by substantial myofiber hypertrophy (+30-40%) in type I and II myofibers from biopsies obtained at 3-10 days post training (Fig.1). In addition, BFRE led to significant gains in MVC (~10%) and RFD (16-21%) (Nielsen et al, ICST 2012).

Underlining the positive influence of SC proliferation on myofiber growth following BFRE, positive relationships were observed between the pre-to-post training change in mean myofiber area and gains in SC number and myonuclei number, respectively ($r = 0.51-0.58$, $p<0.01$).

No changes in any of the above parameters were observed in controls performing similar type of training without blood flow occlusion, except for a transient increase in type I+II myofiber size at 8 days of training.

Potential adaptive mechanisms

Myofiber CSA was found to increase for both fiber types after only 8 days of BFRE intervention (10 training sessions), and remained elevated 3 and 10 days post training (Nielsen et al. 2012). Unexpectedly, fiber CSA also increased transiently in control subjects performing non-occlusion exercise at day 8, but returned to baseline levels after 19 days of training. These observations suggest that the rapid initial change in myofiber CSA was influenced by factors other than myofibrillar protein accumulation, such as cell swelling.

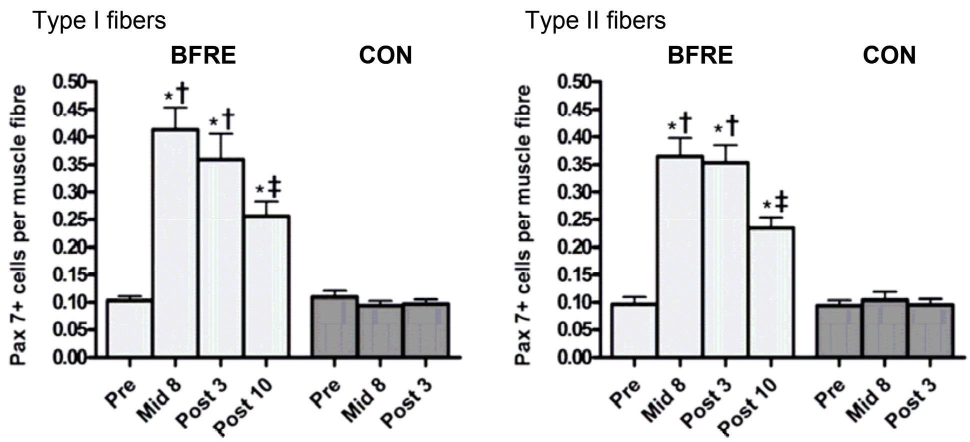

Fig.2 Myogenic satellite cell number pre and post 19 days of blood flow restricted exercise (BFRE) or work/load matched exercise without blood flow occlusion (CON) in type I (left panel) and type II fibers (right panel). Changes relative to pre: * $p<0.001$, between group difference: † $p<0.05$ Adapted from Nielsen et al. 2012.

Short lasting cellular swelling might arise from hypoxia-induced modification of selected membrane channels (Korthuis et al. 1985), stretch-induced opening of membrane channels (Singh & Dhalla 2010) or microfocal damage to the plasma membrane itself (Grembowicz et al. 1999). In contrast, the late-phase gain in myofiber CSA observed following 19 days of BFRE (cf. Fig.1) likely occurred as a result of myofibrillar protein accumulation, since myofiber CSA remained elevated 3–10 days post training along with a 7–11% sustained elevation in MVC and RFD.

The specific pathways of stimulatory action of BFRE on myogenic SCs remain largely unknown. Speculatively, down-regulated myostatin expression following BFRE (Manini et al. 2011, Laurentino et al. 2012) may play an important role, since myostatin is a potent inhibitor of myogenic SC activation (McCroskery et al. 2003, McKay et al. 2012) by suppressing Pax-7 signaling (McFarlane et al. 2008). Induction of IGF splice variants IGF-1Ea and IGF-1Eb (MGF) following BFRE may potentially also play an important role, since known to be strong stimulators of SC proliferation and differentiation (Hawke & Garry 2001, Boldrin et al. 2010). Mechanical stress on muscle fibers can trigger SC activation through the release of nitric oxide (NO) and HGF (Tatsumi et al. 2006, Punch et al. 2009). Consequently, NO may also be of importance for the hyper-activation of myogenic SCs observed with BFRE since transient rises in NO may likely occur in result of the ischemic conditions during BFRE.

For a further discussion of the potential signaling pathways that may activate myogenic satellite cells with BFRE, see conference presentation by Wernbom (ICST 2012).

CONCLUSION

Short-term low-load resistance exercise performed with partial blood flow restriction (BFRE) appears to evoke marked proliferation of myogenic stem cells and to result in myonuclear addition in human skeletal muscle, which contribute to the accelerated time course and marked degree of myofiber hypertrophy observed with this type of training. Tentative molecular signaling events involved in the hyper-activation of SCs by BFRE may involve increases in intramuscular IGF-1 production, local NO release and/or dimished myostatin activity, potentially with a contribution from yet other regulatory factors.

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VIABILITY OF BFR EXERCISE FOR REHABILITATION

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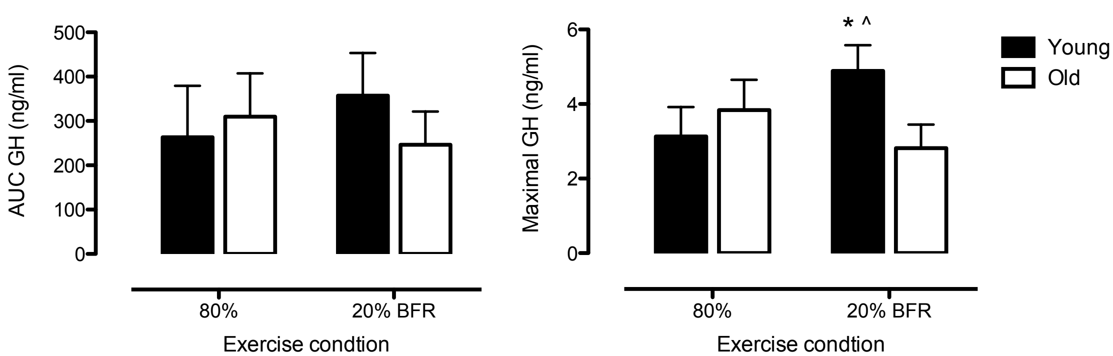
INTRODUCTION

Traditional high-load resistance training performed in excess of 70% of one-repetition maximum (1RM) is the most established means of increasing both muscle and tendon cross-sectional area (CSA) and strength in young and older populations [1,2]. High-load resistance exercise (RE) results in a robust, yet transient, increase in circulating growth hormone (GH) in young individuals, a result which is blunted in older populations [3]. Emerging evidence also indicates that low-load RE performed under conditions of local muscle blood flow restriction (BFR) produces comparable muscle hypertrophy to that observed with traditional high-load RE [4] and that low-load RE alone stimulates intramuscular collagen synthesis [5]. Interestingly, in healthy young persons, low-load RE coupled with BFR increases post-exercise GH concentrations to an equal or greater magnitude than that of high-load RE [6-12]; suggesting that low-load RE with BFR may be an effective means of attenuating metabolic and musculotendinous decrements that occur with aging. However, it remains unknown whether low-load RE with BFR is capable of increasing circulating GH in older populations who typically have low GH concentrations and who exhibit a blunted GH response to traditional high-load RE [3,13,14]. The viability of BFR exercise was evaluated using both efficacy and safety/feasibility assessments. For efficacy, we evaluate the GH response in both young and old adults. Vitals (blood pressure and heart rate), perceived exertion and perceived pain responses were measured to assess the safety/feasibility of low-load RE performed with BFR compared to high-load RE in both healthy young and older adults.

RESULTS/DISCUSSION

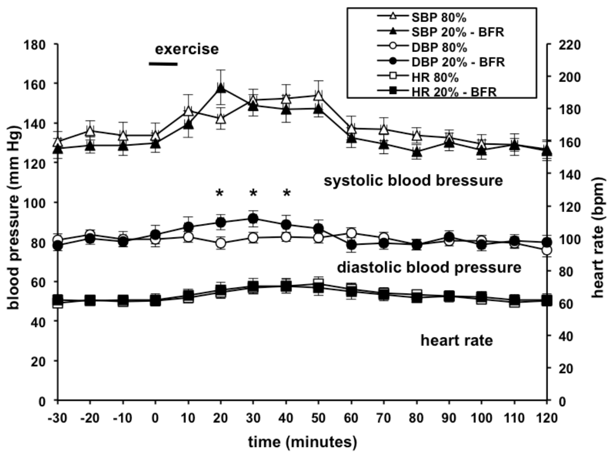
Figure 1 illustrates data according to differences between exercise conditions. The GH responses of young and old subjects were similar between exercise conditions. Knee extension RE at 20% 1RM with BFR had double the GH response to BFR at 40 and 50 minutes post-onset of exercise than old subjects, but these differences were not statistically different ($p = 0.15$ for both time points). There was no difference in the GH response between age groups in the high-load RE condition (all p-values > 0.50). Maximal concentrations of GH were higher in the young during the 20% BFR condition when compared to the old group and the 80% RE condition. GH AUC was similar between age groups and conditions.



Basal plasma IGF-I concentrations were approximately 50% lower in the old compared to young subjects prior to each exercise condition ($p < 0.01$). IGF-I concentrations remained unaltered in young (80% baseline: 273.2 ± 34.8; 80% post-exercise 282 ± 33.5 ng/ml; 20% BFR baseline: 269.0 ± 22.6; 20% BFR post-exercise: 255.4 ± 26.9 ng/ml) and old subjects (80% baseline: 116.9 ± 10.2; 80% post-exercise: 138.4 ± 12.5; 20% BFR baseline: 125.8 ± 10.0; 20% BFR post-exercise: 129.9 ± 14.2 ng/ml) following both exercise conditions.

Heart rate and blood pressure responses are displayed in Figure 2. Both high-load RE and low-load RE with BFR produced a similar, non-significant, elevation of systolic BP (an increase to ~140-150 mmHg) in young and old subjects. Low-load RE with BFR also induced an increase in diastolic BP in young (79.7 ± 2.7 to a maximum of 96.2 ± 4.7 mmHg) and old (78.3 ± 2.7 to a maximum of 90.0 ± 3.9 mmHg) subjects ($p \leq 0.05$) that persisted approximately 30 minutes into recovery.

Elevations in HR were observed between exercise conditions within each age group. Specifically, in young subjects, HR increased a similar magnitude following low-load RE with BFR (baseline HR: 64.0 ± 2.8 bpm; maximum HR: 92.3 ± 3.9 bpm) and high-load RE (baseline HR: 66.4 ± 2.9 bpm; maximum HR: 89.3 ± 5.7 bpm), and remained elevated above resting values for 40-50 minutes following exercise ($p \leq 0.05$). In older subjects HR was also increased following both low-load RE with BFR (baseline HR: 61.8 ± 3.2; maximum HR: 70.4 ± 4.3) and high-load RE (baseline HR: 60.2 ± 3.1; maximum HR: 71.8 ± 4.2) ($p \leq 0.05$), although, the magnitude of increase was less than that which occurred in young subjects



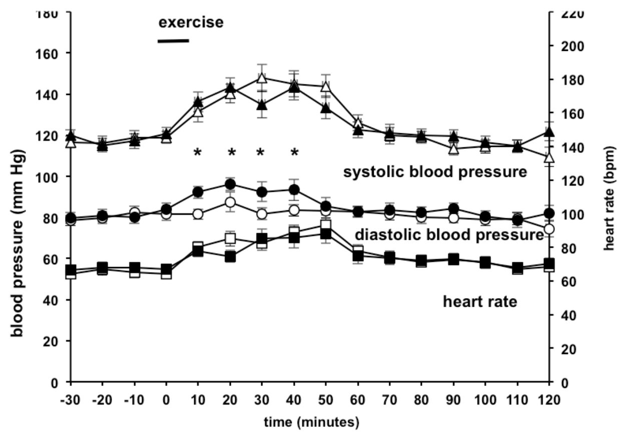


Table 2 displays information on RPE, perceived pain, repetitions achieved and exercise volume. Subjects in both age groups performed a greater exercise volume during the 80% bout of RE compared with the 20% bout with BFR (condition effect: $p < 0.001$). Additionally, when compared to the old, young subjects performed additional repetitions and had a larger exercise volume under both conditions. As seen with the significant age group by condition interaction, young adults also increased their exercise volume from 20% BFR RE to 80% RE to a greater extent than older adults. No differences in RPE were present between age group or exercise condition ($p = 0.387$; Table 2). Conversely, both average and peak pain levels were approximately 2-4 points higher during the low-load RE with BFR compared to the high-load RE in both age groups ($p = 0.003$, Table 2).

Table 2. Rating of perceived exertion (RPE), pain, and total exercise volume in young and old subjects for low-load (20% resistance exercise (RE) with blood flow restriction (BFR) and high-load (80%) RE conditions.

	Young		Old		P-Value		
	20% BFR BFR	80% RE	20% BFR BFR	80% RE	Condition Effect	Age Effect	Conditior Age Intera
RPE (6-20)	17.9 ± 0.5	17.9 ± 0.5	17.6 ± 0.8	18.3 ± 0.4	0.299	0.968	0.387
Average Pain (0-10)	6.3 ± 0.6	4.3 ± 0.7	7.3 ± 0.7	3.9 ± 0.9	0.003	0.733	0.305
Peak Pain (0-10)	7.5 ± 0.5	5.6 ± 0.8	8.7 ± 0.6	4.7 ± 1.1	0.005	0.776	0.211
Repetitions performed ‡	110.3 ± 8.6	46.1 ± 2.1	80.3 ± 12.5	37.5 ± 1.5	< 0.001	0.032	0.146
Exercise volume (rep*kg)	2519 ± 208	4283 ± 312	1722 ± 241	2830 ± 180	<0.001	<0.001	0.055

Note: Exercise volume = total number of repetitions * mass lifted in kg; Average and peak pain calculated over the 5 sets of resistance exercise.
‡ Represents the total number or repetitions achieved over 5 sets of knee extension exercise to volitional failure.

Explanation of acute GH changes in young and old adults

The GH response to RE has been well characterized [15] and is traditionally known to be influenced by chronological age, amount of muscle mass recruited, type of muscle action (concentric or eccentric), exercise load, training status (an athlete versus a sedentary individual), volume of exercise, and the amount of rest given between sets of exercise. In young men, we observed that low-load RE with BFR produces a similar increase in GH to that of high-load RE, which corroborates the findings of several previous studies [6-12]. However, contrary to our hypothesis, we observed that the maximal post-exercise GH response was attenuated in old men during low-load RE with BFR. The GH response to low-load RE with BFR that we observed may seem low compared with that which others report [11]; however, it is of a slightly higher magnitude than that reported by Fry et al., using the same knee exercise protocol in older adults (mean peak response of ~1 ng/ml) [16]. Interestingly, neither low-load RE alone nor BFR alone increase circulating GH concentrations, while the combination of low-load RE with BFR produces a robust increase in GH [12,17]. This suggests that the coupling of these two modalities produces an adjunct elevation in circulating GH that appears to be reliant on both local muscle ischemia and physical exertion.

Explanation of cardiovascular responses to low-load BFR resistance exercise

There has been significant interest in whether low-load RE with BFR alters cardiovascular demands and blood clotting risk through venous stasis. We have previously reported that 4-weeks of low-load RE with BFR has little impact on nerve function, coagulation activity, inflammatory load, and vascular function in young subjects [18]. However, little is known about the acute effects of low-load RE with BFR in older adults. Therefore, we compared heart rate and blood pressure responses between RE with BFR and high-load RE without BFR – a mode that is considered to be relatively safe for most populations [19]. We found that RE with BFR increases diastolic blood pressure to a greater degree than during the high-load RE condition in both age groups. Our data are in agreement with recent evidence demonstrating that the addition of BFR to low-load exercise due to an elevation of total peripheral resistance [12,20] and builds on the reports of others who observed that BFR acutely diminishes stroke volume response and elevates both heart rate [21] and resting blood pressure [22].

Explanation of perceived pain and exertion to low-load BFR resistance exercise

BFR RE resulted in similar reported exertion levels, but higher perceived localized pain during exercise. These results suggest that pain receptors are activated to a greater extent during BFR RE than high-load RE. While the mechanism is not completely clear, its plausible that decreased venous outflow during BRF reduces clearance of metabolic acidosis resulting in activation of proton-activated nociceptors [23]. Importantly, acute pain is known to regulate GH secretion through stimulation of opioid receptors [24]. For example, Greisen and coworkers found a significant increase in GH secretion following electrical stimulation to the abdominal skin [25]. Additionally, Jubeau et al. reported a higher GH secretion with electrical stimulated versus voluntary maximal muscle contractions [26]. The researchers speculated that high acute pain perceived during the stimulated contractions contributed to the elevated GH response. It would appear that the higher levels of pain induced by low-load BFR contributed to the GH release compared to the relatively painless high-load RE bout. From a more applied perspective, elevated pain levels seen during BFR RE reduce its potential utility as a viable modality for the public. A modification of the BFR exercise protocol that minimizes pain levels by releasing cuff pressure between sets of exercise might improve tolerability, but it is unknown how this will impact the physiological responses.

CONCLUSIONS

We report here that low-load RE with BFR stimulates GH secretion in an amount that is comparable to that produced by high-load RE without BFR in young men. However, the post-exercise GH response to low-load RE with BFR is lower in older men when compared with that seen in young men and to some extent compared to traditional high-load RE. Similar cardiovascular responses were observed between exercise modalities in both age groups, with a primary concern being elevated diastolic BP during low-load RE with BFR. Perceived pain was substantially higher in both young and old adults. Additional research is needed to ensure low-load BFR RE is tolerable while providing the physiological signals that are necessary for muscle adaptation.

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PROMOTING STRENGTH AND BALANCE TRAINING FOR EFFECTIVE PREHAB OF KNEE JOINT INJURIES

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There is an ongoing debate about the functional role of the anterior cruciate ligaments (ACL) in knee stabilization. In several papers it has been suggested that the hamstrings play an essential role in ensuring knee stability and that the hamstrings directly protect the ACL while controlling the relative movements of the tibia and the femur. Moreover, in histological studies it has been shown that the ACL with its tensile strength of approximately 2.000 N has not only mechanical importance but also contains different types of mechanoreceptors, preferentially located close to the ligament insertion site. On the basis of electrical stimulation techniques and under functional conditions recent studies on humans presented evidence of an existing reflex arc that between knee joint complex and hamstring muscles (Dyhre-Poulsen and Krogsgaard 2000; Fujita et al. 2000; Gruber et al. 1986; Krogsgaard and Solomonow 2002; Krogsgaard et al. 2002; Miyatsu et al. 1993; Solomonow et al. 1987). The functional role of the hamstring-reflex arc has been described in a way that stress on the ACL activates via reflex loop the hamstring muscles in order to limit anterior dislocations from tiba and femur.
In addition, Friemert et al. (2005) have shown that this reflexive muscle responses consisted of a monosynaptic reflex of the hamstrings (shortlatency
response, SLR), mediated by group I afferents and a later, presumably polysynaptic reflex contribution (medium-latency response, MLR).

Clinical studies investigating joint position reproduction tests, posturography and gait analysis revealed pathological alterations after ACL rupture. Despite successful ACL surgeries, patients report on symptoms of knee instability and complain about feelings of “giving way” that may arise from loss of proprioception. There are, however, also patients who are mechanically instable (no surgery) but don´t show symptoms of “giving way”. In addition, it is still unclear whether the “giving way” phenomenon is associated with mechanical knee instability.

From longitudinal experiments it is known that both strength as well as balance training is able to effectively enhance muscle power. Both training regimen improve the ability to activate muscles and enhance rate of force development. However, based on electrophysiological methods, studies revealed that the functional adaptations of strength and of sensorimotor (balance) training must be differentiated. Spinal excitability (H-Reflex) and corticospinal transmission is differentially adapted and therefore the relative value for knee joint stabilization in prevention or rehabilitation programs are specific.

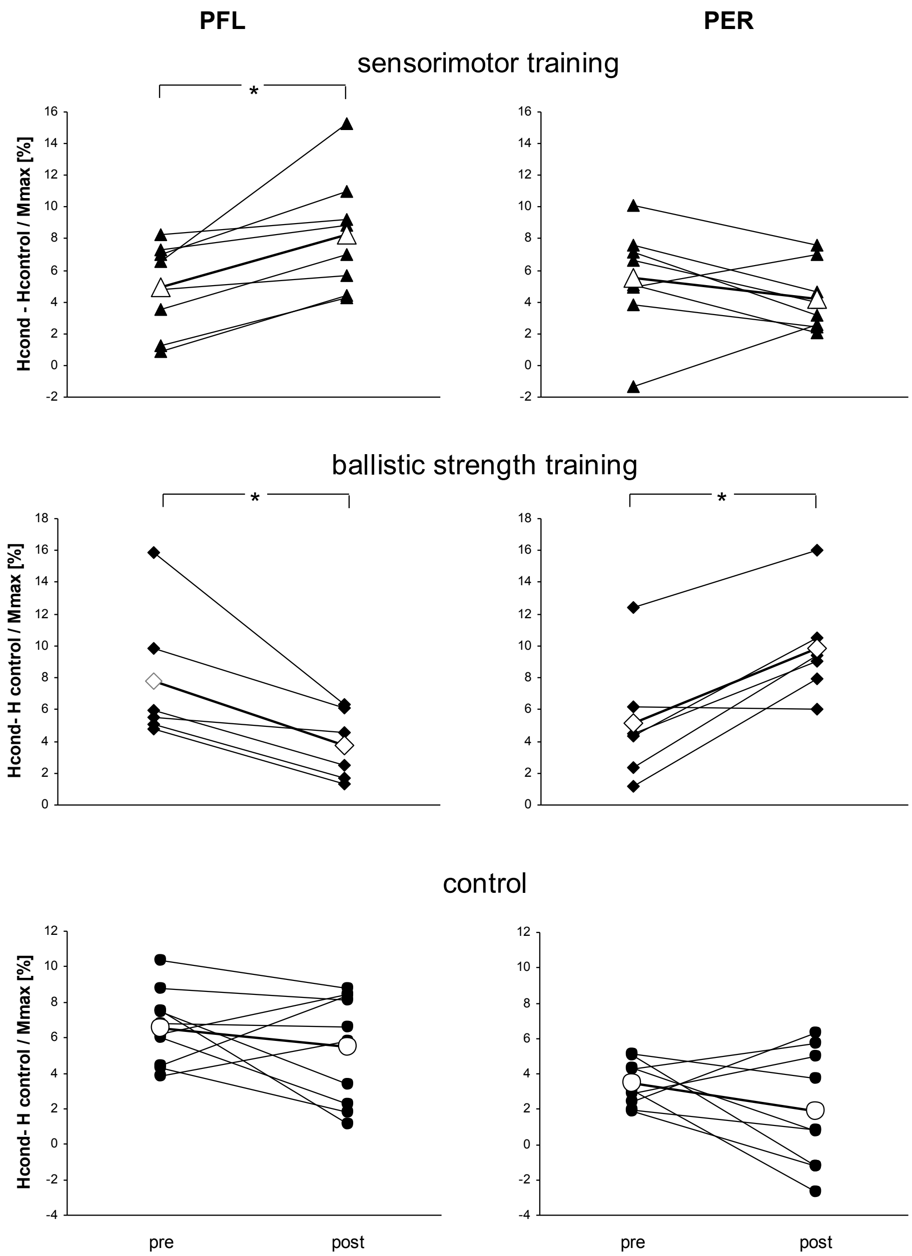

Fig. 1: Individual (filled symbols) and mean (open symbols) values of the conditioned H-Reflex of the M. Soleus during plantar flexion (PFL) and during perturbation (PER) (from Schubert et al. 2008). Subjects performed a 4 wk training program either in the sensorimotor training group, or in the strength training group or in the control group (upper, middle and lower panel).

Programs for prevention of knee joint injuries as well as functional rehabilitation after ACL ruptures must take into consideration that the knee stabilization may be described by two functional aspects: The mechanical function points toward an enhanced strength and power training of both extensor and flexor muscles comprising the joint complex. The functional rational is to provide an active stabilization. The sensor function points towards a progressive sensorimotor or balance training in order to facilitate optimal inter- and intramuscular coordination and to shift motor control from conscious to more automated mode.

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STRENGTH TRAINING – IS THE BRAIN INVOLVED?

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Recent literature indicates that strength training not only affects muscle tissue, but also results in adaptive changes in the central nervous system. However, it is still difficult to find measuring methods to study the neurophysiological details of putative neural adaptations to training. Several research studies used single motor unit recordings, electrical stimulation of peripheral nerves, and non-invasive stimulation of the human brain [i.e. transcranial magnetic stimulation (TMS)] to study neural responses to strength training, however is it possible to measure the plastic changes that occur in the brain after exercise ?

Exercise has an important effect on neurogenesis, improving neural survival and creating new neurons, most of the studies have been performed with endurance training. Here we present a brief overview on possible neural adaptations created by exercise and especially resistance exercise, we present a possible pathway how (resistance) exercise can influence cognition and neurogenesis.

Voluntary strength training (VST) improves the mechanical output of skeletal muscle in healthy humans. Initial increases in force of a maximal voluntary contraction (MVC) are the result of adaptations in the central nervous system. It is now also clear that molecular paths associated with muscle growth also become activated after just a few bouts of weight lifting. Evidence suggests that exercise helps to maintain brain health and cognition and protects against the progressive cognitive decline that is associated with aging (7). Aging is a dynamic and progressive process in which morphological, functional, hemodynamic, and psychological changes reduce the individual's ability to adapt to the environment, thus heightening vulnerability to the onset of pathological processes, with muscle mass and strength and eventually diminishing. Similarly, the central nervous system (CNS) and, therefore, cognitive functioning undergoes changes as people grow older. Colcombe et al. (3) reported neuronal loss starting in the third decade of life with a resulting decline in cognitive performance. Additionally, certain cognitive functions seem to be more susceptible to senescence, such as attention, short and long-term memory, and central executive functions (1). Many studies have shown improved cognitive functions in seniors on an aerobic training program (5). However, little is known about the effects of resistance training on these parameters.

Exercise increases the expression of Brain-derived neurotrophic factor (BDNF) in both the hippocampus and caudal neocortex, demonstrating that BDNF is a neurotrophin that mediates the effects of voluntary physical activity on brain plasticity. According to the literature, the insulin-like growth factor 1 (IGF-1) and BDNF pathways are important targets of physical exercise because the blockage of the hippocampal receptor for IGF-1 (IGF-1R) or BDNF (TrkB) abolishes the effects of exercise on hippocampal plasticity and molecular changes, such as increases in synapsin 1, calcium/calmodulin-dependent kinase II (CaMKII), and mitogen-activated protein kinase II (MAPKII) (2).

With regard to resistance training, results are scarce and BDNF and IGF-1 measurements are limited to systemic measurements. Recent studies that were performed in humans showed that resistance exercise does not alter the BDNF level but increases the IGF-1 level in the blood, whereas aerobic exercise seems to have little or no influence on the serum IGF-1 level (1; 4; 6).

These seemingly conflicting results raise the question of whether resistance training, compared with aerobic exercise, triggers the same cellular signals that are associated with neuronal plasticity. Resistance exercise is strongly recommended for both adults and elders to improve bone mineral mass, muscle mass, strength, and to decrease the risk of falls and functional limitations. Studying the effects of resistance exercise on brain function cannot only reveal additional benefits of this exercise but also help clarify the physiological mechanism underlying brain plasticity.

We report the results of several studies that examined the effects of exercise on brain plasticity and cognition, and explain possible underlying different mechanisms between aerobic exercise and resistance exercise.

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THE EFFECT OF LOW LOAD BLOOD FLOW RESTRICTED RESISTANCE TRAINING IN REHABILITATION OF ELITE ATHLETES

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INTRODUCTION

The Intensive Rehabilitation Unit (IRU) was established in 2009 as a partnership between the British Olympic Association and the English Institute of Sport. The role of the IRU is to deliver intensive, residential, multi-disciplinary rehabilitation to British Olympic athletes. The purpose of the IRU is to accelerate the rehabilitation process of elite athletes in order for them to perform at the Olympic Games. In certain situations, the rate of rehabilitation is limited by muscle atrophy associated with the injury. Traditionally, moderate to large muscle forces are required to stimulate muscle hypertrophy (Wernbom et al., 2007). This could expose the associated joints or injured structures to stress that it simply cannot tolerate. As such, the capacity to promote muscle hypertrophy is limited and the rate of rehabilitation is compromised. Historically at the IRU nutritional interventions and electrical muscle stimulation have been used to attenuate the loss of muscle mass and subsequently promote hypertrophy. However, the time frame of adaptation is typically greater than 6 to 8 weeks for these interventions (Rawson & Volek 2003; Filipovic et al., 2011). This is time that elite athletes do not have in order to compete at the highest level. Blood flow restricted resistance training using low loads (30% 1RM) and high work volumes have been shown to increase muscle hypertrophy and rate of muscle hypertrophy in healthy, non-injured men and women to a greater extent than using resistance training alone (Abe et al., 2005). This appears to be an appropriate solution to the problem of accelerating muscle hypertrophy without compromising healing of the injured structures.

To date, no data have been published on the effect of low load, blood flow restricted resistance training on muscle strength in injured elite athletes. The aim of this body of work was to measure the changes in strength associated with training with low loads and blood flow restriction in elite injured athletes. Additionally, training data was recorded to explore the effects of the volume and intensity of the work done on the associated changes in strength. It is important to note that this body of work was not undertaken using a randomised control study design, but rather a series of n=1 case studies and the pooling of this data in order to audit practice at the IRU.

METHODS

Over a period of 15 months, 20 elite male and female athletes volunteered to use blood flow restricted training on their injured limb. Changes in strength were measured isokinetically for 12 of the athletes and training data were recorded for 16 of the athletes. The athletes were selected for blood flow restricted training if they met the following criteria; 1. Muscle atrophy was related to their injury, 2. Lack of strength limited their function, 3. High joint forces were contra-indicated, 4. They passed the medical screening questionnaire. Following a literature review, two discrete training protocols were used (table 1). A decision was taken on which protocol to use by the IRU team based on volume of other rehabilitation to complete throughout each day. Athletes who had to complete a high work volume throughout the day undertook the once per day training protocol (A, table 1), whilst athletes who weren't capable of undertaking as much other rehabilitation undertook the multiple session per day protocol (B, table 1). Low load blood flow restriction training was used for the muscle groups of the upper and lower extremity. Pearson correlation coefficients were used to determine if there were relationships between selected training variables (volume load, volume, frequency) and change in strength. A student's T-test was used to determine the significance of differences between strength changes in the upper and lower body and between protocol A and B. Finally, to examine whether change in strength was related to starting strength, the initial differences in strength was correlated with the final change in strength and the significant of the differences in change of strength between the stronger and weaker (based on difference in starting strength) were determined using a student's T-test.

Table 1 The details of the two training protocols used

Protocol	Sessions per day	Sets	Reps	Rest	Load	Cuff Pressure
A (Wernbom et al.,)	1	4	To Failure	30 s	40-60RM	Continuous @150mmHg
B (Abe et al.,)	2-3	3	15	30 s	20 RM	Intermittent @150mmHg

RESULTS/DISCUSSION

Two female athletes using protocol B to increase muscle strength of their rotator cuff did not respond to the training programme. They were excluded from the results. The average strength gain was 26% over a period of 9 day training. This change was regardless of protocol used ($p > 0.05$, table 2) or whether the upper or lower body was trained ($p > 0.05$, figure 1).

Table 2. Change in strength associated with use of protocol A and protocol B

Protocool	Sample size	Change in Strength (%)
A	6	28 %
B	12	25 %

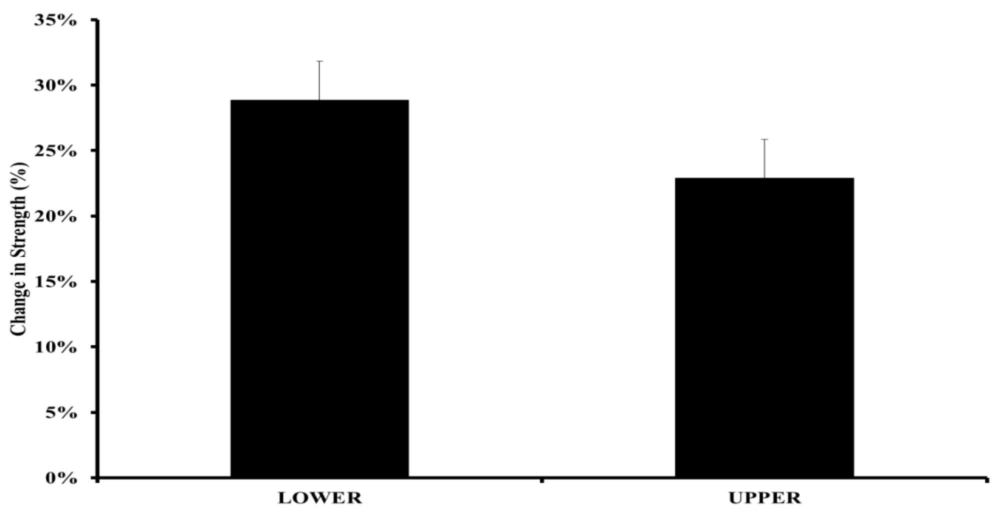

Figure 1. The change in strength associated with using low load blood flow restriction training for the upper and lower body

Significant differences in change in strength were found between the weaker and stronger group ($p<0.05$) and there was a moderate positive relationship found between change in strength and initial strength difference ($r=0.49$).

CONCLUSION

In certain circumstance the rate of rehabilitation from injury is limited by lack of muscle strength. Traditional approaches to increasing muscle strength involve exercising with heavy resistances. Blood flow restriction training with low loads has been used by healthy individuals to increase strength within the literature. This body of work has demonstrated that it is possible to make strength gains using light resistances with injured elite athletes. The use of low load blood flow restriction training was highly effective at improving strength in injured elite athletes. Indeed several athletes competing at the 2012

Olympic Games used occlusion training to accelerate strength gains whilst injured. In keeping with previous research we found that both protocols were equally effective at improving strength (Abe et al., 2005; Wernbom et al., 2006). Additionally, new evidence of strength changes using upper body occlusion training has been found. Further analysis of this data suggests that low load blood flow restriction training is most effective with the weakest of individuals. This has important implications for strength and conditioning coaches and rehabilitators as it demonstrates that athletes who are particularly weak will make large strength gains in a short space of time. This could help to accelerate the rehabilitative process and ensure athletes are safely returning to competition in shorter time frames. Future research could help to understand the mechanisms behind adaptations in the upper body and investigate the critical minimum dose (volume and intensity) required for strength changes.

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IN VIVO TENDON FUNCTION

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Tendons have previously been regarded inert structures that mainly play a role in force transmission from muscle to bone. However, with technological/methodological gains in recent decades, the understanding of *in vivo* tendon function has increased, and although mechanisms are not entirely understood, a large body of literature has emerged to increase the knowledge on i) mechanical function during human movement, ii) tendon response to acute and chronic loading, and iii) tendon properties in relation to performance. The two latter points will be dealt with in subsequent presentations of the current symposium, while tendon function and assessment hereof is addressed in the present communication.

Tendon mechanical properties: In brief, mechanical properties of loaded structures are described by the slope of the load-deformation relation ('stiffness' or its reciprocal 'compliance'). When the physical dimensions of the structure are taken into account a similar factor 'Youngs modulus' is derived as the slope of the stress-strain relation that in turn yields information of material properties. Tendon tissues are viscoelastic, and consequently the load deformation or stress strain plots are not linear but rather display a so-called 'toe region' at low loads where deformation pr. load is greater than at higher loads. Also, stored energy is dissipated upon unloading which is termed 'hysteresis'.

Measurement of tendon mechanical properties: Earlier studies have used animal and/or human cadaver material to examine mechanical properties of the force bearing tissues (Lieber et al. 1991, Scott and Loeb, 1995, Butler et al. 1984, Wren et al. 2001, Haraldsson et al. 2005). Recently, mechanical properties of tendinous tissues have been assessed at microscopical levels by use of atomic force microscopy (Svensson et al 2012). The advantage with *in vitro* experiments is the direct assessment of corresponding values of force and deformation, but the *in vitro* tissue placement may not resemble the *in vivo* setting, and therefore assessment of intact tissues are warranted. Recent methodological and technical advances have enabled assessment of mechanical properties of human tendons during in vivo loading. Ultrasonography (US) has for two decades enabled measurement of tissue movement e.g. tendon displacement during muscle contraction. (Fukashiro et al 1995, Maganaris et al 1999, Magnusson et al 2001, 2003, Kubo et al 2002, Seynnes et al 2009). Initially slow isometric contractions were applied, but with increasing time resolution also tendon function during dynamic high force contractions have been examined (Ishikawa et al. 2007). The technique has been improved and refined, and when care is taken it seems likely that valid measurements can be obtained, although it should be noted that no gold standard exists. Additional imaging techniques have been applied, and by use of so-called 'cine phase contrast MRI' tendinous and/or muscle tissues can be tracked in 3 dimensions during voluntary (repetitive, submaximal) contraction efforts (Finni et al. 2003).

Tendon mechanical structure: The two human tendons that are subject to most *in vivo* investigations are the Achilles and the patellar tendon. Both tendons are involved in, -and undergo heavy loading during human locomotion. Nonetheless these tendons display distinct differences with respect to tendon structure. Firstly, the patella tendon, or at least a significant part of it originates and inserts on bone (therefore at times termed lig. patella), while the Achilles tendon originates from three separately innervated muscles. Secondly, while the patella tendon has a large CSA relative to its length, the opposite is the case for the Achilles tendon. Moreover, the tendons seem to differ in design such that the patella tendon mostly consists of parallel fascicle bundles, while the Achilles tendon is rotated so fascicle bundles that origin from medial aspects of the gastrocnemius tend to insert posteriorly on the calcaneus, while fascicles from the lateral gastrocnemius and soleus rotate antero-medially (Cummins et al. 1946, Szaro et al 2009). The functional significance of tendon rotation is not known, but is has been suggested to contribute to energy storage properties of the structure, which in fact is an important feature of the Achilles tendon. With respect to cross sectional area (CSA) the two tendons are more similar in design such that the CSA increases going from proximal to distal (Kongsgaard et al 2005, 2007, Seynnes 2009). Differences in CSA influences per definition tendon stress, which in turn may play a role for injury, and frequent injury sites in both tendons are those of lesser CSA. With respect to loading during forceful movements the Achilles tendon operates at higher loads relative to its strength, which likely contributes to the high frequency of rupture compared to that of the patella tendon.

FORCE TRANSFER

Tendons or the 'aponeurosis-tendon unit' have traditionally been considered homogenous force bearing structures, but as indicated above this may not be the case. Firstly, it is unclear if the mechanical properties of the aponeurosis differ from that of the free tendon despite serial connection and similar tissue properties. It seems that that the experimental setting (i.e. cadaver vs. *in vivo*) influences the mechanical properties such that stiffness of the *in vivo* aponeurosis exceeds that of the free tendon (Magnusson et al. 2003), while the opposite may be the case in a cadaver preparation. This discrepancy is attributed to the active contracting muscle fibers that in the *in vivo* setting anchor on the aponeurosis resulting in augmented stiffness compared to that of the cadaver setting where load is applied externally (Magnusson et al 2008). Differences in mechanical properties have also been observed within different regions of the human patellar tendon such that fascicles of the anterior part of the tendon displayed significantly greater modulus compared to fascicles of the posterior aspect of the tendon (Haraldsson et al 2005). Cadaver studies have confirmed that separate loading of separate triceps surae muscles lead to heterogeneous loading of the Achilles tendon (Arndt et al. 1999), and a recent study using similar methods demonstrated that also joint configuration i.e. calcaneal in- or eversion contributed to non-uniform tendon strain (Lersch et al. 2012). In vivo studies have indicated uneven Achilles tendon loading by tracking of muscle movement with US in different joint configurations (Bojsen-Møller et al 2004), and a study where needles were inserted transversely through the tendon during maximal plantarflexor contractions yielded direct evidence of non uniform tendon deformation since needles were permanently distorted upon retraction (Magnusson et al. 2003). Non uniform soleus tendon-aponeurosis deformation, has further been observed in vivo by use of cine phase MRI during plantarflexor efforts (Finni et al. 2003). Taken together, these studies provide evidence of intratendinous shear stress with a pattern related to muscle activation and joint configuration, and further that stress concentrations, that in turn may play a role for injury, are likely to occur within force bearing tissues *in vivo*.

A recent body of literature has examined if force can be transmitted laterally within a limb where muscles and tendons are situated in close proximity. In animal models intermuscular force transmission has been shown to occur between muscle synergists and even antagonists, and also force transfer was seen from muscle to bone although the muscle had no insertion to the bone (Huijing et al 2007, 2008). An *in vivo* study mimicked the above setting by manipulating joint angles and single muscle contractions while measuring associated muscle movements with US (Bojsen-Moller et al. 2010). Also in the *in vivo* experiment some evidence of lateral force transmission was seen, however, the functional significance of such a mechanism is yet to be understood (Maas and Sandercock 2008, Herbert et al. 2008).

Conclusion: Recent investigations have indicated that the *in vivo* function of the tendon-aponeurosis unit is complex, and that mechanical properties of force bearing tissues may well be influenced by the interface between contractile and force transmitting tissues. Moreover, force transmission within aponeuroses and tendons may occur in a heterogenous manner governed by muscle activation and joint configuration. The functional consequence and relation to e.g. overuse/acute injury remains to be understood.

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TENDON ADAPTATION IN RESPONSE TO CHRONIC LOADING/STRENGTH TRAINING

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Tendons have long been regarded as mere connections between muscle and bone, with little metabolic activity. However, research from the past two decades shows that tendinous tissue displays a collagen anabolic response and undergoes morphological and mechanical changes when subjected to increased loading.

TENDON METABOLIC RESPONSE TO INCREASED LOADING

Notwithstanding the relatively low occurrence of fibroblasts and a rather limited vascularity, tendons have been shown to be metabolically responsive structures, even at low stress levels (1). Animal and human studies indicates that exercise (single or repeated bouts) induces an increase in collagen synthesis (type I and III), supported by an elevated metalloproteinase enzymatic activity and the release of growth factors such as IGF-I and TGF-β-1 (2–4). This anabolic activity has hitherto been ascribed to both transcriptional and translational levels. However, this paradigm was recently challenged by a study on human patellar tendon (5) showing that, in contrast to skeletal muscle, no significant change in mRNA expression of collagen, growth factors and other extracellular matrix (glycoproteins) components is observed in response to one bout of kicking exercise. These findings suggest that the metabolic response to mechanical stimulus is lower in tendon than muscle and that collagen synthesis may be primarily supported by an increased translation rate in human tendons.

The common belief is that newly synthesized collagen is deposited into the fibrillar structure, making tendons stiffer and stronger and, eventually, increasing their cross-sectional area (CSA). This assumption is consistent with *in vitro* data showing an association between fibril area fraction and material properties (6) but evidence is currently lacking to support a link between these properties and fibril diameter per se. On the other hand, larger fibril diameter may improve tendon tensile strength via a higher probability of crosslinking between collagen molecules. An increase in the number of molecular cross-links could indeed contribute to the training-induced increase in tendon material properties. However, studies supporting this are scarce and, thus far, this phenomenon was only observed in the animal model (4; 7).

MATERIAL AND MORPHOLOGICAL ADAPTATIONS TO TRAINING

The precise links between the tendon metabolic response to increased loading and changes observed at macroscopic level remain elusive. Nevertheless, changes in mechanical properties have been found almost systematically in trained individuals. *In vivo*, these variables are systematically assessed with ultrasound-based techniques. The wide range of methodological approaches and their limitations currently masks the precise dose-response relationship of these changes (Figure 1). However, studies indicate that increases in tendon stiffness range from 15% to 71% after a few weeks of training (8–12). Conversely, the effects of resistance training on the capacity to retain elastic energy, another important functional feature of tendons, do not seem clearly established (13; 14).

From a structural point of view, an increase in tendon stiffness could be linked to either changes in material properties or a larger CSA. An increase in Young's modulus - a variable reflecting material properties - has in fact been observed in most training studies (11; 15–17) (Figure 1). However, unlike reports from animal studies (18) and cross-sectional observations in athletes (19), changes in tendon CSA following resistance training were not demonstrated until recently (9; 10). These late observations are probably due to the confinement of tendon hypertrophy (9; 10; 20) to regions where stress is likely concentrated; previous studies assessing average CSA or inappropriate tendon regions may have overlooked this phenomenon.

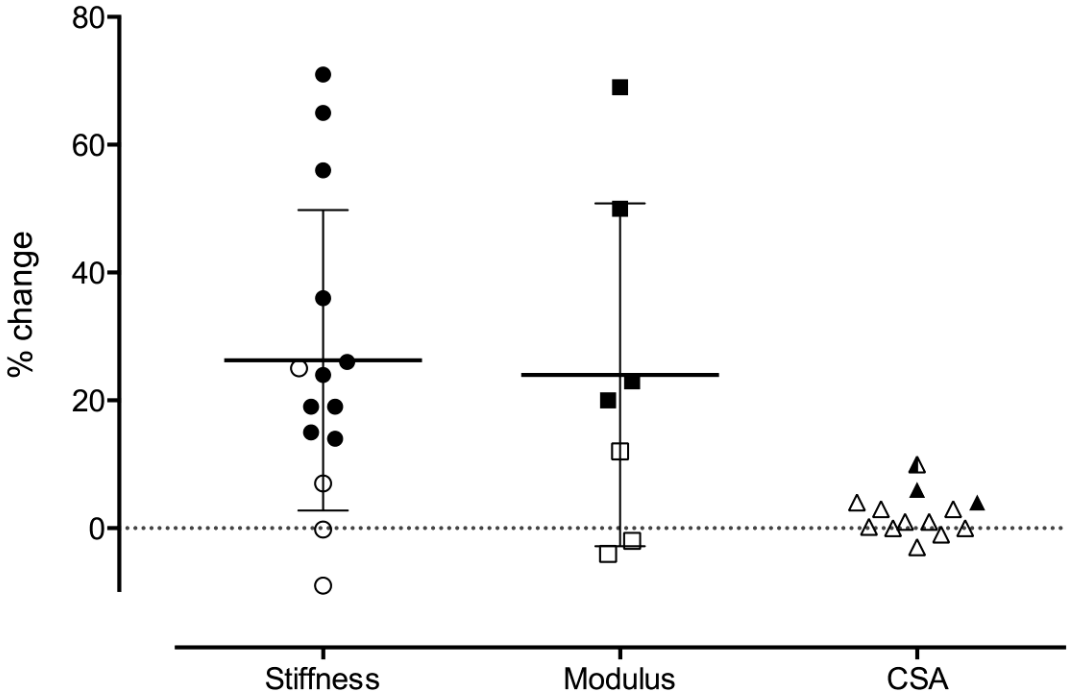

Figure 1: The effects of short-term resistance training on patellar and Achilles tendons. Significant (filled symbols) and non-significant (empty symbols) changes observed after 8 to 15 weeks of resistive exercise. Half-filled symbol denotes estimated mean change. References: (8–12; 15; 16; 21; 22)

Hence, strength training and activities involving impacts (e.g. running) induce increases in tendon stiffness, tensile modulus and CSA. However, the time course and relative magnitude of these changes differ considerably between studies and the exact mechanisms underpinning tendon adaptation are largely unknown. Stresses (23) and strains (10) higher than those experienced in daily activities are prerequisites but other factors such as overall loading volume – as opposed to loading magnitude alone – also seem to influence tendinous adaptations to training (11).

INFLUENCE OF DISUSE, AGEING AND SEX

In line with these postulated mechanisms, a decrease in muscular activity and force- generating capacity has been shown to result in the deterioration of tendon properties (24; 25). Yet, the long-term decline in muscle size and function associated with ageing and disuse do not seem to affect tendon mechanics consistently (26). In fact, age-related changes in tendon composition (i.e. decreased collagen content vs. increased collagen cross-links) may contribute to maintain tendon mechanical properties. Furthermore, the tendon capacity to adapt to resistive exercise seems preserved in older individuals (16). Conversely, tendon adaptations to increased loading seem affected by sexual dimorphism, with reduced mechanical and morphological changes and a blunted collagen metabolic responsiveness in women (27).

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TENDON PROPERTIES IN RELATION TO OPTIMAL SPORTS PERFORMANCE

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It is well accepted that tendon mechanical properties influence the function of the entire muscle-tendon unit. Those properties do not only affect force transmission but also have an important implication on energy storage and recovery (Alexander, 2002). Additionally, the mechanical properties of the tendons are essential for the function of muscles during locomotion as they are acting in-series. The compliance of the tendon and aponeurosis allows an independent behavior of the muscle fascicles enabling those to contract at lower shortening velocities than the entire muscle–tendon unit (Ettema et al., 1990).

Studies with hopping wallabies or running turkeys, where tendon force and muscle fascicles length could be directly measured, gave evidence that most of the positive work done by the entire muscle-tendon unit comes from the recoil of the tendon and, that muscle fascicles change length only marginally (Biewener et al., 1998, Roberts et al., 1997). However, metabolic energy is still required to generate muscle force, needed to operate tendons as springs. This can be accomplished at lower cost when a muscle contracts almost isometrically or is briefly stretched (Hill, 1938, Woledge et al., 1985). Recent technical advances in the ultrasonographic technique provide the possibility to directly observe human muscle and tendon behavior during different locomotor activities in vivo (Aggelousis et al., 2009, Fukunaga et al., 2001; Ishikawa et al., 2005, 2007; Kawakami et al., 2002; Lichtwark et al., 2007; Spanjaard et al., 2007). For running it has been shown that muscle fascicles of the gastrocnemius medialis shorten during the entire contact phase (Ishikawa et al., 2007; Lichtwark et al., 2007). In contrast to the gastrocnemius fascicles, the muscle-tendon unit is lengthened during the breaking phase and shortened during the propulsion phase, which indicates that energy is stored in the series-elastic element during the breaking phase and recoiled during the propulsion phase. As discussed by Lichtwark et al. (2007), muscle fascicles never exceed a shortening velocity of 1.5 fascicle lengths per second and at peak tendon force the shortening velocity does not exceed 0.54 fascicle lengths per second. Thus, in contrast to the series-elastic element, the shortening velocity of the muscle fascicles is low and favorable for economical force generation. The recoil of the series-elastic element during the propulsion phase is responsible for a high power output exceeding the possible power output of a muscle predicted by the force-velocity relationship (Hof et al., 2002), also described as the 'catapult' effect (Alexander and Bennet-Clark, 1977).

Tendon's compliance is determined by their cross-sectional area, length and material properties. Having the same material properties, a thin and long tendon would show a higher compliance and a higher energy storage capacity compared to a thick and short tendon for the same given tendon force. Thus, muscle tendon units having short fascicles with a pennated architecture and a long thin tendon are deemed favorable to economical force generation and elastic energy savings (Biewener & Roberts, 2000). Lichtwark & Barclay (2010) also showed that increasing tendon compliance increases peak power output. However, increasing tendon compliance impairs force transmission and therefore may also affects the rate of force development (Bojsen-Møller et al., 2005), reflex response, control of joint position and movement accuracy (Rack et al.,1983; Rack & Ross, 1984). Further, as the muscle and tendon are acting in-series, tendon lengthening and lengthening velocity have to match the muscle's operating range, due to the force-length and force-velocity relationship (Biewener & Roberts, 2000).

Using a model of the gastrocnemius medialis muscle-tendon unit, Lichtwark and Wilson (2007, 2008) showed the existence of optimal tendon compliance to maximize efficiency during walking and running. They showed that i) increasing or decreasing tendon compliance beyond optimal values would reduce efficiency and that, ii) optimum tendon compliance depends on fascicle length and is specific for the given movement task (Lichtwark & Wilson, 2008). Thus, tendon compliance likely affects sports performance and may have the potential to explain inter-individual differences. Studies describing a relation between performance and tendon mechanical properties are rare and mostly limited to modeling (e.g., Albracht & Arampatzis, 2006, Bobbert et al., 2001, Miller et al. 2012). Existing in vivo data demonstrate that tendon properties are related to performance in movements involving stretch-shortening cycles (e.g. Arampatzis et al., 2006, Bojsen-Moller et al., 2005; Kubo et al., 1999, 2000; Stafilidis & Arampatzis, 2007). In general, higher muscle strength is accompanied with lower tendon compliance (Arampatzis et al., 2007, Couppe et al., 2007; Kubo et al., 2011). However, in a homogenous group of elite sprinter it was not possible to find a significant correlation between muscle strength and tendon compliance of the knee extensors (Kubo et al., 2011), suggesting that other factors may also affect tendon compliance in athletes. Using a model, Miller et al. (2012) showed that removing the compliance of the series-elastic component (i.e., no deformation of the series-elastic element) in all muscle-tendon units reduce maximum sprinting velocity of the model by 26%. Existing in vivo data for sprint running indicates that a more compliant tendon at the knee extensors is favorable for sprint performance (Kubo et al., 2000, Stafilidis and Arampatzis, 2007). Although a recent study (Kubo et al., 2011) failed to observe a correlation between 100 m racing time and tendon compliance in elite male sprinters, tendon compliance was significantly higher in this group than in sedentary controls with similar knee extensor muscle strength. A more compliant tendon at the knee extensors seem to be advantageous for running economy (Arampatzis et al., 2006) and 5000 m race time (Kubo et al., 2010) in long-distance runners, as well.

For the triceps surae tendon, no effect of compliance on sprint performance has been observed (Kubo et al., 2000, 2011, Stafilidis & Arampatzis, 2007). For long-distance running the reported results about the triceps surae tendon are discrepant. Kubo et al. (2010) reports a significant correlation between 5000 m race time and tendon compliance, meaning that a more compliant tendon is beneficial for endurance running. Arampatzis et al. (2006) showed that more economical runners show greater plantarflexion muscle strength and lower tendon-aponeurosis compliance at the triceps surae muscle-tendon unit. To study the effect of triceps surae tendon compliance on running economy, a decrease in tendon compliance (~15%) and an increase in plantarflexion strength (~7%) was induced by a resistance training in recreational long distance runners (Albracht & Arampatzis, 2012). After 14 weeks intervention, subjects showed a significant reduction (~4%) in energy cost of running. However, there was no reduction in the amplitude of shortening or shortening velocity of the gastrocnemius muscle fascicles determined during the stance phase using ultrasonography. Nevertheless, the reduced energy cost of running after decreasing triceps surae tendon compliance and increasing contractile strength, indicates that force generation within the lower extremities has become more efficient while running. The underlying mechanisms of these findings are not completely understood and require further research. In addition to tendon compliance, viscoelastic properties (i.e. the energy that is lost during loading and unloading) may also be considered.

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DETERMINANTS OF PERFORMANCE IN ENDURANCE SPORTS

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Maximal (peak) oxygen uptake, the lactate threshold and efficiency during exercise are often regarded as major determinants of endurance performance.

Maximal oxygen uptake

An individual's maximal oxygen uptake is limited primarily by cardiac output, locomotory blood flow and the oxygen-carrying capacity of the blood (Kanstrup & Ekblom, 1984; Andersen & Saltin, 1985; Levine, 2008). Furthermore, maximal oxygen uptake is proportional to the volume density of mitochondria in muscle (Weibel & Hoppeler, 2005). Elite endurance athletes can exhibit maximal cardiac outputs in excess of 40 $L \cdot min^{-1}$ and stroke volumes larger than 200 mL, with a maximal oxygen uptake greater than 6 $L \cdot min^{-1}$ (Ekblom & Hermansen, 1968) and relative values of approximately 80-90 $ml \cdot kg^{-1} \cdot min^{-1}$ (Bergh & Forsberg, 1992).

The lactate threshold

Although extensive maximal oxygen uptake is a prerequisite for high-level endurance performance, the capacity to maintain a high workload with a lower concentration of lactate in the blood is often a more reliable indicator of such performance (Coyle *et al.*, 1991; Lucia *et al.*, 2004). Endurance athletes can maintain a power output and/or speed for long periods that is twice as high as those of active non-athletes before exceeding the lactate threshold, because of their elevated capacity for mitochondrial oxidation of fatty acids (Coyle & Joyner, 2008).

Efficiency

Work economy/efficiency (i.e., the amount of oxygen that must be consumed in order to generate a given speed or power output) may differ between athletes with different levels of performance, varying by 30–40% among runners (Farrell *et al.*, 1979; Conley & Krahenbuhl, 1980; Joyner, 1991), but generally somewhat less in cyclists (Coyle, 1995). This efficiency is influenced by several factors, including biomechanical predisposition, neuromuscular recruitment of muscles and fibers, the distribution of blood flow and mitochondrial efficiency (perhaps the P/O ratio may vary).

Accordingly, training that enhances maximal oxygen uptake, the lactate threshold (capacity for fatty acid oxidation) and/or power output at or below this threshold, and exercise efficiency is crucial to excellent performance in endurance sports.
In addition, several other factors, discussed below, are significant in this context.

Capacity for anaerobic energy production

The contribution of anaerobic energy production during an endurance competition varies depending on the distance covered and the nature of the sport. For example, during a 15-km cross-country skiing race of approximately 40 minutes, this contribution has been estimated to account for approximately 10% of the total energy production, a value that increases to 20% during a 5-km race (Saltin, 1997). In connection with sprint skiing (4 sessions of 2.30-3 min each), the mean rate of work on uphill stretches is approximately 160% of the peak aerobic power (Sandbakk *et al.*, 2011) and in other types of endurance sports involving comparable racing times, about 20–30% of the total energy is supplied by anaerobic processes (Gastin, 2001). The higher uphill values during sprint skiing probably reflect recovery while going downhill, enabling the skier to generate greater anaerobic power on uphill terrain.

Strength/power/speed

Training designed to enhance strength and/or power can improve endurance performance by increasing mechanical/technical efficiency and/or reducing the relative intensity of a muscular action (Millet *et al.*, 2002). The required level of maximal strength/power depends both on the sport and the duration of the event.

Elite endurance athletes normally perform exercises designed to enhance strength 1-4 times a week, with the relative amounts of general and specific strength-oriented training, as well as the nature of the training, differing between sports and individual athletes. Coaches and athletes strive to convert the ability to produce force into more efficient locomotion and relevant sport-specific movements, which appear to be particularly important in sports involving rapid movements and more complex technique. It is notable that enhanced power is often described as an important benefit of tapering, whereas endurance training with high volumes often produces the opposite effect.

Technique and equipment

The influence of technique on elite endurance performance, although well-known, has been much less investigated (Holmberg, 2007). Two of the most striking paradigm shifts in this connection are the Fosbury flop, first used in Mexico City in 1968, and the V-style ski jumping. Other innovations that have improved endurance performance include the double-poling technique in cross-country skiing and alterations in swimming techniques. In addition, developments in equipment such as aerodynamic wheels and helmets for cycling, the wing-paddle for kayaking and new suits for swimming have enhanced performance substantially.

Training

Elite endurance athletes train 10-12 times a week and 600-1000 hours each year (Matsson & Holmberg, 2012), approximately 90-95% of which is endurance training. About 70-75% of this annual training is performed at lower intensities and 10-20% at higher intensities. Although most endurance athletes follow polarized endurance training models they also perform training with medium intensity; the proportion of exercise at different intensity zones varies during the season. The amount of total training at low, medium and high intensity is considered to be important for attaining maximal endurance potential.

Our understanding of training practices continues to evolve with knowledge that high-intensity interval training (Helgerud *et al.*, 2001) and maximal repeated sprints demonstrated to improve aerobic capacity to an extent similar to that achieved by more traditional, relatively low-intensity endurance training (Gibala *et al.*, 2006; Burgomaster *et al.*, 2008; Perry *et al.*, 2010; Seiler *et al.*, 2011). These improvements are associated with activation of molecular signaling pathways involved in regulating mitochondrial biogenesis (Bartlett *et al.*, 2012). At the same time, low-intensity endurance training (below the lactate threshold) results in adaptations that are significant for specific aspects of performance and that do not occur with high-intensity training alone (Esteve-Lanao *et al.*, 2007; Ingham *et al.*, 2008; Laursen, 2010).

For successful athletic outcomes it is vital to be aware of the multiple factors that affect endurance performance and to understand the training practices that are effective in improving endurance capacity.

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STRENGTH TRAINING IN ENDURANCE SPORTS: PROS AND CONS

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The effects of strength training on endurance athletic performance have been the subject of a long and ongoing debate among athletes, coaches and sport scientists. Performance in most endurance events is determined by the maximal sustained power production for a given competition distance, and the energy cost of maintaining a given competition speed. In shorter endurance events and during accelerations and sprint situations, anaerobic capacity and maximal speed may also contribute to performance. Strength training could thus contribute to enhance endurance performance by improving the economy of movement, delaying fatigue, improving anaerobic capacity and enhancing maximal speed. (Aagaard et al. 2010).

Several investigations have shown the above improvements as a result of high-intensity strength and plyometric training. This has been shown to be the case in various endurance sports including male and female cross-country skiing (Hoff et al. 1999, Hoff et al. 2002, Losnegard et al. 2011), cycling (Rønnestad et al. 2011, Sunde et al. 2010), running (Støren et al. 2008), and triathlon (Millet et al. 2002). In most cases, strength training had no significant effect on determinants of endurance performance such as maximal oxygen uptake (VO_{2max}) (Saunders et al. 2006, Spurrs et al. 2003), and the gains in movement economy are often attributed to mechanisms residing within the skeletal muscles, such as increased lower leg musculontendinous stiffness (Spurrs et al. 2003) and/or improvements in running mechanics (Saunders et al. 2006).

Replacing a portion of endurance training with explosive strength training can contribute to performance of trained cyclists (Bastiaans et al. 2001) and runners (Paavolainen et al. 1999). In terms of neuromuscular and anaerobic characteristics, concurrent explosive strength and endurance training can result in improved maximal anaerobic speed, and selective neuromuscular performance characteristics including concentric and isometric leg extensión forces in runners (Mikkola et al. 2007). Nevertheless, it has also been found that although concurrent resistance and endurance training in well-trained cyclists enhanced 1RM strength, it did not improve overall cycle time trial performance and reduced 1-km final cycle sprint performance compared with a control group performing their normal cycle training (Levin et al. 2009).

A potential counter productive outcome of strength training is that muscle hypertrophy could have a negative impact on weight-bearing endurance events. Also, an increase in myofiber cross-sectional area could reduce capillary to muscle fiber cross-sectional area ratio, thus increasing difussion distance (Aagaard et al. 2010). In this respect, it is worth mentioning that 12 weeks of supplemental strength training improved determinants of performance in Nordic Combined by improving the athletes' strength and vertical jump ability without increasing total body mass or compromising the development of VO_{2max} (Rønnestad et al. 2012). Losnegard et al. (2011) also found that 12 weeks of supplemental heavy strength training improved the strength in leg and upper body muscles of male and female elite cross-country skiers, but had little effect on the muscle CSA in thigh muscles. The supplemental strength training improved both VO_{2max} during skate-rollerskiing and double-poling performance. Other researchers have also found no change in body mass as a result of strength training in endurance runners (Støren et al. 2008) and cyclists (Sunde et al. 2010).

With regards to muscle capillarisation and perfusion, there is no reason to fear that they may be compromised by strength training. Indeed, capillary density does not seem to decrease with strength training in untrained subjects (Green et al. 2009), and 16 weeks of concurrent strength and endurance training did not negatively affect muscle capillarisation in a group of trained cyclists (Aagaard et al. 2011).

In summary, although early studies on the impact of strength training on endurance performance provided inconclusive results, recent research on highly trained athletes suggests that strength training can be successfully prescribed to enhance endurance performance. The mechanisms involved in the observed performance gains may include a conversion of fast-twitch type IIX fibers into more fatigue resistant type IIa fibers, increased muscle strength and rate of force development, and improved neuromuscular function and musculotendinous stiffness, without a change in muscle capillarization (Aagaard et al. 2011).

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NEUROMUSCULAR ADAPTATIONS TO COMBINED STRENGTH AND ENDURANCE TRAINING

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Strength training leads to specific neuromuscular adaptations (in the central and peripheral neural control as well as in muscle tissue associated with hypertrophy) responsible, to a large extent, for improved strength of the trained muscles. Endurance training enhances aerobic performance by improving maximal oxygen uptake (VO_{2max}, oxidative capacity) and increasing muscle aerobic enzyme activities, intramuscular glycogen stores, as well as capillary and mitochondrial density in the muscles. It is important to study the magnitude and time course of neuromuscular adaptations during combined strength and endurance training in both previously untrained subjects and endurance athletes.

ACUTE RESPONSES AND NEUROMUSCULAR CHANGES DURING STRENGTH TRAINING

Acute responses: Heavy Resistance "Neural" protocol (HRN) performed with high loads (such as 80-90-100% of 1RM) but only a low number of repetitions (such as 1-5) per sets leads to acute fatigue in the neuromuscular system observed as great acute decreases in maximal voluntary activation and strength of the exercised muscles. Heavy Resistance "Hypertrophic" protocol (HRH) performed with medium high loads (such as 60-85% of 1RM) but multiple repetitions of 6-12 in each set (until concentric action failure) leads to drastic acute fatigue in the neuromuscular performance and e.g. to large acute hormone responses. "Explosive" Resistance protocol (ER) performed with lower loads (such as 30-60% of 1RM) but high movement velocities leads to acute decreases during the initial parts of the IEMG- and force-time curves accompanied by minor metabolic responses.

Chronic adaptations: The gains in maximal strength during initial weeks of strength training in previously untrained subjects of both genders may be largely accounted for by neural adaptations. This can be measured e.g. using specific recordings of voluntary actions combined with electrical stimulation procedures, using invasive techniques of needle or fine-wire electrodes insertions into muscle, H-reflex and V-wave measures, evoked cortical potentials or by analysing changes in EMG activity of trained muscles during maximal voluntary actions. Although EMG is a complicated signal, the increase in the quantity of EMG suggests that the number of motor units recruited have increased and/or motor units are firing at higher rates or a combination of the two has occurred. The quantity and quality of activation can change due to strength training so that 1) activation of the agonists is increased (increase in efferent motor drive; increased motor unit firing frequency; enhanced motor unit synchronization; increased motoneuron excitability; down regulation of inhibitory pathways), and there is 2) an improved coactivation of the synergists and 3) a reduction in coactivation of the antagonists (Aagaard & Thorstensson 2002). Training-induced muscle hypertrophy contributes to an increasing extent to strength gains as HR training proceeds. Hypertrophy is measured by analyzing the size of individual muscle fibers or muscle CSA by a means of US, CT or MRI. Male bodybuilders use typical HRH protocols and show the ultimate degree of muscle hypertrophy. The increase in muscle CSA during HR training comes primarily from the increase in size of individual muscle fibres probably with no addition in fibre number. High tension of a muscle for a sufficient duration provides the signal for increased uptake of amino acids and enhanced synthesis of contractile proteins. The repeated process of damage and repair during and between training sessions may result in an overshoot of protein synthesis. Serum hormones and intra-muscular signalling pathways interact and work independently. Resistance exercise elicits an acute hormonal response modified by the protocol (intensity, volume, muscle mass involvement, rest intervals etc.), training background, age, gender, and nutrition etc. The acute response may be more critical to tissue growth and remodeling than chronic changes in resting hormonal concentrations, since several training studies have not shown systematic changes despite muscle hypertrophy and strength gains. Nevertheless, adaptations to resistance

training entail four general classifications: 1) acute changes during and post- resistance exercise, 2) chronic changes in resting conditions, 3) chronic changes in the acute response to resistance exercise, and 4) changes in receptor content (Kraemer & Ratamess 2005). The basic serum levels of anabolic and catabolic hormones usually remain within normal physiological range in men and women during HR training. More information is needed on hormonal adaptations including expression and contents of androgen receptors and hormone-receptor interaction during short-term and prolonged HR training in order to optimize the individual training process and avoid overtraining in athletes.
It is important to note that HR training with slow action velocities usually leads only to minor gains in high velocity portions of the force-velocity or initial portions of the isometric force-time curves (Häkkinen 1994). Because the effective time taken by muscles to contract in several athletic activities is very short, special attention is needed to plan proper strength and power training programs for athletes including endurance events. Thus, ER training with lower loads but high movement velocities results in gains in high velocity force portions of the force-velocity curve, while the gains in maximal strength remain minor compared to high load HR training. Neural activation of the agonists during ER exercises is high, but the time of this activation is short and acute anabolic response low leading to minor training-induced hypertrophy. However, ER training can lead to an increase in the rapid neural activation of the agonists observed e.g. during the initial portions of the IEMG- and force-time curves, as well as to a decrease in the antagonist coactivation. The increase of rapid neural agonist activation comes from increases in the firing frequency of motor units and brief interspike intervals or “doublets” in the EMG burst (Van Cutsem et al. 1998, Häkkinen 1994).

SHORT-TERM AND PROLONGED COMBINED STRENGTH AND ENDURANCE TRAINING

Previously untrained subjects: The physiological stimuli and signals directed to skeletal muscle as a result of strength training and endurance training are divergent in nature. However, muscle strength can be increased during concurrent training in previously untrained subjects, almost as much as during strength training alone, provided the concurrent training period is short and the training volume is rather low (e.g. Wilson et al. 2012). Concurrent training may not impair adaptations in strength, muscle hypertrophy, and neural activation induced by strength training over a short-term period (McCarthy et al. 2002). However, concurrent training might interfere or inhibit strength development, if the concurrent training period is too long and the training volume/frequency and/or intensity are too high (Leveritt et al. 1999). The "interference effect" was initially described by Hickson (1980) when he noticed that combined training with a high overall volume had no interference on strength gains during the first weeks of training, but a plateau occurred after 5-6 weeks of training, followed by decreased strength during the last 7-10 weeks of the training period.

When the volume of concurrent training is high, skeletal muscle may not be able to adapt metabolically or morphologically to both strength and endurance training due to different or even opposing adaptations at the muscle level. Limited strength gains over a prolonged training period may be due to a limited and/or a reduced hypertrophy of individual muscle fibres (Kraemer et al 1995). A minor change in the size of muscle may be partly due to the oxidative stress imposed on the muscle and the need to optimize the kinetics of oxygen transfer due to the addition of endurance training to strength training. The compatibility may also have an overreaching/overtraining aspect to it as well. When the overall volume of training is high, simultaneous training for both strength and endurance may be associated with large strength gains during initial weeks of training but with only limited strength development later on. The physiological basis for this may be linked to an interaction between an elevated catabolic hormonal status leading to a reduced change in muscle CSA. The degree of the antagonism that occurs as a result of combined strength and endurance training may also differ based on the nature of the strength training and the target goal. Power seems to be more susceptible to limited gains than strength during concurrent training (Wilson et al. 2012, Häkkinen et al. 2003). The mode of endurance training is also important, since running seems to more susceptible than cycling to interfered strength gains during combined endurance and strength training (Wilson et al. 2012).

The volume of concurrent strength and endurance training can be diluted by a longer period of time with a low frequency of training. Strength training for 21 weeks (addressing both strength and power) with simultaneous endurance training (2+2 sessions a week) resulted in large gains in maximal strength accompanied with increased maximal voluntary activation of the trained agonists as well as enlargements in the muscle CSA and sizes of muscle fibres (Häkkinen et al. 2003). The magnitudes of these increases did not differ from the corresponding changes obtained during strength training alone. The strength training program alone led to gains in rapid force production associated with increases in rapid neural activation of the trained muscles. However, no changes took place in the rapid neuromuscular characteristics, when strength training was combined with endurance training. Thus, even the low frequency of concurrent strength and endurance training may lead to interference in explosive strength development, probably mediated in part by inhibited rapid voluntary activation capacity in the neuromuscular system. As training for physical fitness calls for gains in muscle strength, power and endurance, the construction and periodical prioritization of maximal and explosive strength and/or endurance exercises becomes important for overall fitness training.

Endurance athletes: The role of explosive strength and power is important for various athletic purposes including endurance athletes. The gains in neuromuscular performance over a short period of time such as 6- 10 weeks may not be fully inhibited by concurrent explosive strength and endurance training (Paavolainen et al. 1999, Mikkola et al. 2007). Explosive strength training-induced increase in the early portions of the IEMG-time curve indicated that the gains observed in explosive strength of leg extensors in endurance athletes was largely due to neural adaptations (Mikkola et al. 2007). The gains in explosive strength in endurance athletes over 8 weeks of training could be obtained without the decrease in aerobic capacity.

Effects of prolonged combined strength and endurance training, especially maximal vs. explosive strength training performed concurrently with endurance training on muscle activation, CSA and strength development as well as endurance performance were studied recently (Taipale et al. 2010, 2012a, Mikkola et al. 2011, 2012) in recreationally trained endurance male runners. Significant gains in dynamic maximal strength occurred in both maximal and explosive strength trained groups, whereas the strength gains in the control group (endurance and typical circuit training) were minor. In the maximal strength trained group the increase in maximal strength over the 14-week training period was somewhat larger than in the explosive strength trained group. The plateau in strength gains in both groups that occurred following week 10 indicate that the strength training stimulus was not large enough to induce further changes, or may indicate some interference of high volume endurance training on strength development (see also Wilson et al. 2012). Nevertheless, the strength gains in both groups were associated with increased voluntary muscle activation of leg extensors. The maximal strength trained group also made some gains in muscle CSA but the magnitude of the increase remained limited, since no HRHP was included in the program, and because subjects were participating concurrently in high volume endurance training. Significant gains were also observed in explosive strength in both maximal and explosive strength trained groups (Taipale et al. 2010) indicating a limitation of neuromuscular specificity of training during concurrent training. Interestingly, in endurance runners with no strength training background, maximal strength training had more of an effect on power than the more specific explosive strength training. The fact that subjects also did endurance training, mostly running, may have inhibited specific adaptations to the explosive resistance training program used.

Taipale et al. (2012a) examined effects of 1) mixed maximal and explosive strength training, 2) maximal strength training, and 3) explosive strength training performing concurrently with endurance training over an 8-week period. The three groups were “more effective” during this period than circuit training in increasing maximal strength and power. The three groups performing a low volume of strength training did not, however, differ from each other with regard to strength and power gains while concurrently performing a higher volume of endurance training. It seems that gains in strength and power may be highly individual, thus performing the more diverse mixture of maximal and explosive strength training in a way that meets individual needs may be more effective than either maximal or explosive strength training combined with endurance training. Moreover, there may be additional benefits to increased strength and power over a more prolonged training period e.g. improved economy (Taipale et al. 2010). Maximal and explosive strength training is more useful in endurance athletes than hypertrophic type of training (Aagaard & Andersen 2010).

The 14-week strength training period in endurance runners in the study by Taipale et al. (2010) was followed by another 14-week period of the reduced volume of strength training. Significant decreases occurred in maximal strength and muscle activation of leg extensors in the maximal strength trained group, while in the explosive strength and circuit groups these variables remained unaltered. Decreases in maximal strength and muscle activation are typically associated with reduced strength training volume during strength training only (Häkkinen 1994). The decreases were possibly also influenced by the increased endurance running volume that took place during the 14-week reduced strength training period. This reduced strength training did not provide enough of a strength training stimulus to maintain increases in muscle activation and strength made during the preceding strength training period. The increases in maximal oxygen uptake (VO_{2max}) were minor in all three training groups (Taipale et al. 2010). Importantly, significant gains took place in maximal running velocity at the maximal oxygen uptake (vVO_{2max}) in all three groups over the 14-week strength training period. However, this increase only continued in both maximal and explosive strength trained groups over the reduced volume strength training period. Furthermore, improvement in running economy also occurred in both groups over the strength training and/or reduced strength training periods. Though increases in VO_{2max} were minimal, improved muscular activation and increased strength and power induced by both maximal and explosive strength training influenced endurance performance, prepared subjects for an increase in endurance training volume, and improved their sport-specific economy. These observations are consistent with data by Paavolainen et al. (1999) who attributed improved endurance performance to sport- specific economy and improved neuromuscular function. Maximal strength training has improved anaerobic performance capacity (Mikkola et al. 2011) giving some advantage to real competitive performance, especially for sprinting actions at the end of the race. The study by Taipale et al (2010) also showed that serum concentrations of testosterone and cortisol remained unaltered over the entire 28-week study in all three training groups indicating maintained homeostatic control. However, the serum ratio of T/C decreased in the maximal strength trained group following reduced strength training. Typical male endurance athletes have been reported to have suppressed resting concentrations of testosterone and elevated levels of cortisol. The reduced strength training period, which included an increase in endurance training, appears to have increased catabolic activity in the strength group possibly contributing to strength and power decreases.

A recent study (Taipale et al. 2012b) compared the effects of mixed maximal and explosive strength training on neuromuscular and cardiorespiratory performance in male and female endurance runners. The gains in maximal and explosive strength and muscle activation appeared to, in combination with endurance training, contribute to enhanced endurance performance by improving peak running speed and submaximal running characteristics. Increased economy has been also observed in cyclists (Ronnestad et al. 2011). The male and female endurance runners had differences in their time-course of neuromuscular adaptations and men made more systematic improvements than women in submaximal running variables despite women making larger strength gains. The increase in serum testosterone in the male group suggests that the initial weeks of training stimulated an anabolic environment in the body, while the subsequent decrease in testosterone during the final weeks of training indicates increased stress as the volume and intensity of combined training increased. Mixed strength training combined with endurance training can be used in male and female endurance athletes to promote gains in both force and selected endurance performance characteristics.

In conclusion, both maximal and explosive strength training performed concurrently with endurance training seem to be effective in improving strength, power and muscular activation in endurance runners. The gains obtained from maximal and explosive strength training appear to prepare subjects for increased endurance training volume and coincide with gains in aerobic performance including vVO_2 and running economy. The gains in strength and power may be highly individual, thus performing the more diverse mixture of maximal and explosive strength training in a way that meets individual needs may be more effective than either maximal or explosive strength training alone. Further information is needed about acute neuromuscular and hormonal responses to single session combined strength and endurance exercise using the two opposite exercise orders and comparison of chronic adaptations of these two training modes to those taking place during separate day combined strength and endurance training.

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EFFECT OF STRENGTH TRAINING ON CYCLING PERFORMANCE

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INTRODUCTION

Substantial effort and resources are invested in studying various training methods that have the potential to enhance cycling performance. Incorporation of strength training in cyclists' preparatory period for a new season, has received increasing attention during the last two decades. Pate & Krista (1984) presented a model for explaining long-term endurance performance that incorporates three major factors: i) VO_{2max}, ii) the fraction of VO_{2max} which can be sustained for an extended period of time, often expressed via the lactate threshold, and iii) work economy; numerous studies support this model (e.g. di Prampero et al. 1986, Joyner & Coyle 2008, Midgley et al. 2007). Therefore, the model will be used as a framework for examining the effects – on cycling performance and on the determinants of cycling performance – of adding strength training to normal endurance training.

MAXIMAL OXYGEN CONSUMPTION

Little evidence exists to support the idea that strength training should be the primary training mode to improve the maximal oxygen consumption (VO_{2max}). There seems to be neither a positive nor negative effect of concurrent strength and endurance training compared to endurance training alone regarding VO_{2max} adaptations in trained cyclists (Bastiaans et al. 2001, Bishop et al. 1999, Hickson et al. 1988, Levin et al. 2009, Rønnestad et al. 20010a; 2010b, Sunde et al. 2010, Aagaard et al. 2011). However, it should be noted that the majority of the training interventions investigating the effects of concurrent training last between 8 and 12 weeks, thus caution should be used when long-term effects of concurrent training are considered.

LACTATE THRESHOLD

There is discrepancy in the literature when it comes to the effect of concurrent strength and endurance training on cyclists' power output at lactate threshold (e.g. power output at a set blood lactate concentration ([la^-]). Some studies reports improved power output at a certain [la^-] (Koninckx et al. 2010, Rønnestad et al. 2010a; 2010b), while other studies reports no additional effect of performing strength training (Bishop et al. 1999, Sunde et al. 2010, Aagaard et al. 2011). Even though the reason(s) to these different findings remains unknown, it might be related to a low strength training volume with only one exercise in two of the latter studies (Bishop et al. 1999, Sunde et al. 2010, while a higher volume with multiple leg exercises were used in the studies finding a positive effect of strength training. That being said, also larger strength training volumes has been reported to not affect power output at a certain [la^-] (Aagaard et al. 2011). Importantly, none of the studies on cyclists reports a negative effect of strength training on power output at the lactate threshold.

It has been suggested that power output at a set [la^-] may be related to the amount of muscle mass sharing the power output (Coyle et al. 1988). Meaning that that strength training induced increase in muscle mass of the primary power generating muscles in the pedal thrust may reduce the single muscle fibres` requirement of resynthesis of ATP and has therefore been suggested to positively affect the lactate threshold (Coyle et al. 1988). Furthermore, power output at a set [la^-] is amongst others, also largely affected by the cycling economy. It would therefore be expected that an improved power output at lactate threshold with no change in VO_{2max}, is accompanied by an improved cycling economy. However, this is not always the case.

CYCLING ECONOMY

When cycling economy is measured by the traditional method by short (3-5 min) submaximal bouts of exercise, the main finding in the literature is no change after a period where cyclists combined heavy strength training (Rønnestad et al. 2010a, 2010b, Aagaard et al. 2011) or explosive strength training (Bastiaans et al. 2001) with endurance training. To the contrary, adding heavy strength training to endurance training in trained cyclists has also been reported to improve cycling economy after only 8 weeks of training (Sunde et al. 2010). The reasons for this discrepancy remain unclear, but the lower performance level of the cyclists in the latter study may affect the outcome of strength training. Interestingly, by using a non-traditional protocol to measure cycling economy, an improved cycling economy was observed after a period of concurrent strength and endurance training (Rønnestad et al. 2011). Cycling economy was measured during 5-min periods every half hour throughout 3 hours of submaximal cycling. During the first 2 h of cycling, there was no difference between the strength training group and the control group in economy, but during the last hour the changes from pre- to post-intervention became significantly different between groups (Rønnestad et al. 2011). This finding may be related to an increased contribution to power production, due to increased strength and thus postponed fatigue, by the efficient type I muscle fibres. In summary, divergent findings exist on whether performing heavy strength training together with ordinary endurance training improves cycling economy. This may be due to methodological differences. There are no reports of negative effect of strength training on cycling economy.

OTHER FACTORS IMPORTANT FOR CYCLING PERFORMANCE

Performance in cycling road races depends on a number of factors in addition to those mentioned above. It has been shown that peak aerobic power output (W_{max}) distinguishes well-trained cyclists from elite cyclists, making it a well-suited predictor of cycling performance (Lucia et al. 1998). The reason for this is probably that W_{max} is influenced not only by VO_{2max} and cycling economy, but also incorporates anaerobic capacity and neuromuscular characteristics (Jones & Carter 2000). Power output determines velocity during cycling and thus greatly affects performance. Therefore, it is interesting to note that concurrent endurance and heavy strength training has been reported to increase W_{max} to a larger extent than endurance training alone (Rønnestad et al. 2010a, 2010b). However, this positive effect on W_{max} was neither observed after replacing a portion of the endurance training with explosive strength training (Bastiaans et al. 2001) or after short term (6 wks.) strength training (Levin et al. 2009). Another important factor for cycling performance is the ability to generate high power output over a short period of time. This ability is essential when the cyclist needs to close a gap, break away from the pack, or win a final sprint. Peak power output in a Wingate test is greatly affected by muscle cross- sectional area (Izquierdo et al. 2004) and it has been shown Wingate peak power output was improved in cyclists after a period of combined heavy strength training and endurance training (Rønnestad et al. 2010a). This observed improvement is probably due to increased leg strength.

CYCLING PERFORMANCE

The traditional way of measuring cycling performance in test laboratories is by performing time trials lasting between 30 and 60 minutes. In such time trials there have been observed both advantageous adaptations after adding strength training (Hickson et al. 1988, Koninckx et al. 2010, Rønnestad et al. 2010b, Aagaard et al. 2011) and no additional effect (Bastiaans et al. 2001, Bishop et al. 1999, Levin et al. 2009). When positive effects are reported, heavy strength training is performed with multiple leg exercises and when no additional effect is reported, this may be related to a short-term strength training period, low volume of strength training or that explosive strength training is performed.

Another method to measure endurance performance is to simulate a mass start in road cycling by cycling at a submaximal exercise intensity during 3 hours, and thereafter performing a 5 min all- out trial (Rønnestad et al. 2011). Adding heavy strength training to regular endurance training have been reported to increase mean power output production during a 5-min all-out trial performed following 3 hours of submaximal cycling, while no changes occurred in the endurance training group (Rønnestad et al. 2011). Interestingly, after the strength training period the cyclists achieved superior reductions in oxygen consumption, rate of perceived exertion, [la^-], and heart rate than the control cyclists during the last hour of the 3 hour submaximal cycling (Rønnestad et al. 2011). One interpretation is that the strength-trained cyclists were further from exhaustion at the end of the 3 hour submaximal cycling and therefore capable of producing higher mean power output during the final 5-min all-out trial. In agreement with the present results, lowered heart rate at the end of 2 hours submaximal cycling has been observed after 5 weeks of heavy strength training in triathletes (Hausswirth et al. 2010).

POTENTIAL MECHANISMS

While the specific causes for the seemingly favourable adaptation in cycling performance (when combining heavy strength training and endurance training) are unclear, a likely mechanism may be related to muscle fibre type recruitment pattern. Strength training increases maximal force and therefore will the peak force or muscle-fibre tension developed in each pedal thrust decrease to a lower percentage of the maximal values. Indeed, in a cross-sectional study of cyclists with similar VO_{2max} and W_{max}, lower EMG activity has been observed in the cyclists with high maximal strength than in the cyclists with low maximal strength (Bieuzen et al. 2007). Further, according to the size principle of motor unit recruitment (Henneman et al. 1965), the following may be hypothesized: a reduced reliance on the less efficient type II muscle fibres and thus improved cycling economy, slower emptying of glycogen stores, reduced overall muscle fatigue, and a potentially increased capacity for high-intensity performance following prolonged cycling or an increased ability by the cyclist to ride longer until exhaustion (Coyle et al. 1992, Hickson et al. 1988, Horowitz et al. 1994).

Another putative mechanism which has frequently been put forward to explain improvement in endurance-related measurements after concurrent training is that increased maximum force and/or RFD may allow better blood flow to exercising muscles (Sunde et al. 2010, Aagaard et al. 2011). This is explained by the assumption that a lowering of the relative exercise intensity will induce less constriction of the blood flow. Alternatively, improved RFD may allow a shorter time for the restriction of blood flow due to reduction in time to reach the desired force in each movement cycle. A shorter contraction time or shorter time with relative high force production in working muscles may therefore increase the blood flow to the muscles. Whether blood flow is enhanced after a period of concurrent strength and endurance training has not been thorough investigated, but in theory will an increase in blood flow, and thereby increased delivery of O_2 and substrates to the working muscles, indeed contribute to increased long-term endurance performance.

CONCLUSION

In cycling, there are contrasting findings in the literature, but when heavy strength training is performed with multiple exercises in addition endurance training during an extended period it seems like endurance performance is improved. It is suggested that the main reason to improved long-term performance in cyclists is postponed activation of less efficient type II fibres or improved blood flow in working muscles. Importantly, no negative effects of adding strength training are reported.

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CHANGES IN STRENGTH AND FUNCTIONAL CAPACITY WITH AGING: HOW DO WE IMPLEMENT STRENGTH TRAINING IN ELDERLY AND WHICH IMPROVEMENTS CAN WE EXPECT?

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INTRODUCTION

Although the term sarcopenia has taken on various definitions since the original use by Rosenberg (1) over the past decade it has evolved into an equivocal designation of vulnerability to weakness, disability, and diminished independence among aging adults. Indeed, decreases in muscle tissue quantity and quality may begin to occur prior to the fourth decade and gradually worsen through the later stages of adulthood. However, these age-related changes in morphological and functional characteristics of skeletal muscle are often accompanied by other comorbid conditions which may cluster and serve to worsen the severity of sarcopenia. In particular, various cardiometabolic factors such as chronic inflammation and oxidative stress (2), insulin resistance (3), skeletal muscle fibrosis (4), myosteatosis (i.e. intra- and intermuscular adipose tissue infiltration), reduced mitochondrial area density and function (5-7), and increased overall fat mass (i.e. sarcopenic obesity) (8-10), are known to be coincident with, caused by, or exacerbated through the trajectory of aging. Thus, despite the ongoing conjecture regarding its classification as a disease state versus the ubiquitous process of normal aging, sarcopenia represents a very complex phenotype with a multifactorial etiology. Central to the pathophysiology of sarcopenia and related comorbidities, physical inactivity is consistently recognized as a predominant and perennial "cause (11)." Thus, since sarcopenia is robustly associated with weakness, frailty and mobility disability (12, 13), failure to prevent its progression with behavioral interventions including physical activity (PA), structured exercise, and lifestyle modification may significantly impede optimal quality of life and lead to early mortality (14-16).

Several potent behavioral factors are recognized to independently contribute to onset and progression of sarcopenia and related comorbidity, including obesity, physical inactivity, smoking, and malnutrition. Of these factors, physical inactivity is perhaps the most detrimental for propagating impairment of function throughout late adulthood, and along with insufficient dietary provisions, is the risk component that has received the most research attention for treating age-related atrophy and weakness. Indeed, ample evidence exists to confirm a robust, independent association between sedentary behavior and disease, disability and shortened lifespan among older adults (17). Despite this rather simplistic and predictable trajectory of age-related decline, substantial debate persists regarding the optimal strategy to slow or reverse the downward spiral of muscle tissue integrity and function (18).

Concerns of elevated risk associated with activity for older adults have prompted a minimalistic paradigm, and a general trend of non-progressive, yet safe activity suggestions. However, and as an important point of clarification, "activity participation" should not be interpreted as merely the inverse of "inactivity." Although maintenance or increases in aerobic PA is known to support preservation of function and longevity (17), there are also well-recognized health benefits associated with structured and progressive resistance exercise (RE). Moreover, since muscle weakness and atrophy are predictive of functional deficit, disability, and early all-cause mortality among older adults (13, 19-21), RE may be considered the primary preventive or treatment strategy in this population. However, at present only 27% of the population [U.S.] is estimated to participate in leisure time RE, and these rates are dramatically less for individuals over the age of 50 years (22). Moreover, although the effectiveness of RE for older adults has been deemed to be supported by the highest category of evidence (i.e. "Evidence Category A.") (23), the overall reported value of RE for strength and hypertrophy among aging persons is inconsistent across investigations. Debate concerning the appropriateness of RE among older individuals has cultivated questions regarding general efficacy and safety for this population, particularly as applies to progression of training. There are very few published accounts that have examined the overall benefit of RE in aging persons while considering a continuum of dosage schemes, treatment durations, and/or age ranges on longitudinal adaptation. As a result, current PA recommendations for older adults include guidelines for RE (23, 24), albeit at minimal dosages and not specific to sarcopenia or disability treatment/prevention.

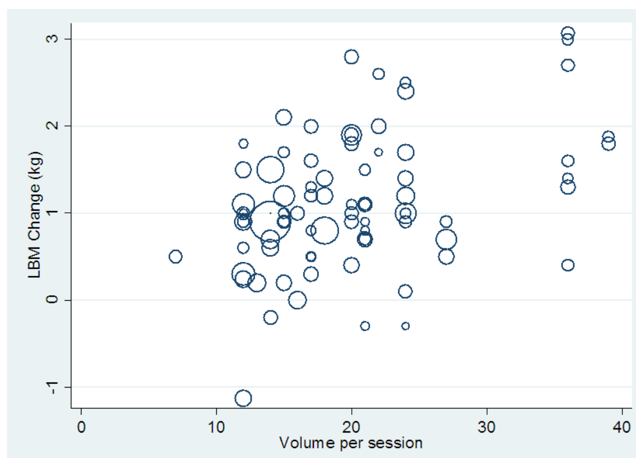
The extent of sarcopenia and weakness is widely variable among older adults, which is suggested to be attributable to the peak in mass and strength attained earlier in life (25). Thus, even though significant adaptation is possible in the oldest old (26), it may be expected that the benefits of early intervention will translate to preservation of long-term health and independence. Previous studies have documented a disproportionate decline of strength and muscle mass, which suggests that these age-related phenomena are somewhat independent (27, 28). Further, there is a robust association between strength deficit and diminished functional capacity (29, 30), and although the rate of decline is largely an individual phenomenon, further decrement may be mitigated with early detection and RE participation. Several investigations have reported that after even short durations of RE, protein synthesis rate and neuromuscular adaptive-responses among elderly adults were similar to that of young subjects, despite a much lower pre-exercise rate (31-34).

EXERCISE PRESCRIPTION

The current guidelines for RE are very different between young and middle-aged healthy adults (35, 36), and those sanctioned for elderly populations (23, 24, 37). Most notably, and in spite of a significant body of literature to support the safety and effectiveness of higher-dose training, current recommendations for older adults do not endorse progression to accommodate long-term adaptation. Current guidelines call for RE to be performed two or more nonconsecutive days per week, using only a single set of 8-10 exercises for the whole body, and at a moderate (5-6 RPE out of 10) to vigorous (7-8 RPE out of 10) level of effort that allows 8-12 repetitions (23, 24). Although there is indeed sufficient evidence to support the short term efficacy of low-dose RE for strength improvement among older adults (38), there is now ample evidence to confirm the viability of progressive RE for improving strength and muscle mass over the long term. Specifically, evidence from two recent meta-analyses (39, 40) has revealed that RE is effective for eliciting significant strength adaptation and increases in lean body mass among older adults, and that there is a dose-response relationship such that volume and intensity are strongly associated with adaptation.

Volume: Training volume (i.e. as denoted by the total number of performed sets of resistance exercise) is independently associated with greater increases in lean body mass (**Figure 1**). Training volume may be operationalized per session, however unpublished data from this analysis revealed that volume per week was also a significant predictor of lean body mass increase (41). Based on these findings, it is possible to manipulate respective dosage by altering (1) the total number of exercises, (2) the number of sets performed per exercise, and/or (3) the number of training sessions per week, making this a simplistic and adaptable parameter of total training volume.

Figure 1. Lean Body Mass Change by Training Volume (sets per session), weighted by number of subjects in the study.



Intensity: For full-body strength capacity, training intensity (i.e. as denoted by percentage of 1-repetition maximum) was determined to be a significant predictor such that higher intensities were reflective of greater absolute and relative improvements (39). Intensity was categorized into (1) low (< 60% 1-repetition maximum), (2) low/moderate (60-69% 1-repetition maximum), (3) moderate/high (70-79% 1-repetition maximum), and (4) high (≥ 80% 1-repetition maximum). Each incremental increase in intensity category was reflective of an approximate 5.5% increase in respective strength outcome.

These findings reflect and support the viability of progression in RE dosage to accommodate a hierarchical adaptive-response to training. Progressive RE should thus be encouraged among healthy adults, regardless of age, to minimize degenerative muscular morphology and dysfunction. However, as is generally accepted for any novice trainees, prescription of RE should always include a familiarization period, in which very low dosage training (i.e. minimal sets and intensity) takes place 1-2 times per week. Following the familiarization, it may be expected that older adults can benefit from gradual increases in training dosage to accommodate improvements in strength and muscle hypertrophy (**Table 1**). Additional suggestions pertaining to progression in RE include (1) gradual increases in intensity from moderate (i.e. 50-70% of 1-RM [12-15 RM]; or 5-6 RPE out of 10) to vigorous (i.e. 70–85% of 1-RM [6-10RM]; or 7-8 RPE out of 10), (2) gradual increases in the number of sets from a single set-, to as many as three or four sets per muscle group, (3) gradual decreases in the number of repetitions performed (i.e. to coincide with progressively heavier loading), from 12–15 repetitions per set, to approximately 6-10 repetitions per set, and (4) progression in mode from primarily body weight or machine-based resistance exercise to machine plus free-weight resistance exercise (18).

Table 1. Sample 6-month progressive resistance exercise model for healthy, older adults (Adapted and modified with permission from Peterson, MD (41)).

Training Dosage	Weeks 1-8				Weeks 9-16				Weeks 17-24			
	Weeks 1-2	Weeks 3-4	Weeks 5-6	Weeks 7-8	Weeks 9-10	Weeks 11-12	Weeks 13-14	Weeks 15-16	Weeks 17-18	Weeks 19-20	Weeks 21-22	Weeks 23-24
Volume (# Sets/muscle group)	1	1	1-2	1-2	2	2	2	2-3	2-3	2-3	2-3	2-3
Intensity (Training Load)	15-20 RM	15-20 RM	15 RM	15 RM	12 RM	12 RM	10 RM	10 RM	8-10 RM	8-10 RM	6-8 RM	6-8 RM
Frequency/Split	1-2/Full Body	1-2/Full Body	2/Full Body	2-3/Full Body	2-3/Full Body	2-3/Full Body	3/Full Body	3/Full Body	3/Full Body	3/Full Body -or- Split: 2 Upper/2 Lower	Split: 2 Upper/2 Lower	Split: 2 Upper/2 Lower
Training Agenda	Familiarization	Familiarization	Familiarization	Muscular Endurance	Muscular Endurance & Hypertrophy	Muscular Endurance & Hypertrophy	Muscuolar Hypertrophy & Strength	Muscuolar Hypertrophy & Strength	Muscuolar Hypertrophy & Strength	Muscular Strength	Muscular Strength	Muscular Strength
Rest Period Between Sets (sec)	n/a	n/a	60-90 sec	60-90 sec	90 sec	90 sec	90 sec	90-120 sec	90-120 sec	120 sec	120-180 sec	120-180 sec
Mode (Exercise choices)	Body Weight; Postural / Stabilization; Selectorized Machines	Body Weight; Postural / Stabilization; Selectorized Machines	Body Weight; Postural / Stabilization; Selectorized Machines	Body Weight; Postural / Stabilization; Selectorized Machines	Postural / Stabilization; Selectorized Machines	Postural / Stabilization; Selectorized Machines; Free Weights	Postural / Stabilization; Selectorized Machines; Free Weights	Postural / Stabilization; Selectorized Machines; Free Weights	Selectorized Machines; Free Weights	Selectorized Machines; Free Weights	Selectorized Machines; Free Weights	Selectorized Machines; Free Weights

***Volume**: The number of sets for a given muscle group, per training session. **Intensity**: Load that corresponds with a maximal number of repetitions (RM) (e.g. 10RM: load that corresponds with approximately 10 allowable repetitions). **Frequency**: The number of times per week each muscle group should be trained. **Split**: The partitioning of RE for specific body parts (e.g. Full Body: resistance exercises are performed for all major muscle groups in a given session). **Training Agenda**: The purpose for a given period of RE (i.e. Familiarization: A period of time devoted to gaining familiarity with the RE). **Rest Period between Sets**: The minimum amount of time devoted to rest/recovery between successive sets of RE for a given muscle group. **Mode**: The type of RE movements and loading parameters.

CONCLUSIONS

Due to the disproportionate degree of muscle atrophy and strength decline of the lower limb musculature during aging (42), an RE intervention model for positive effects on lower-extremity strength is recommended to provide enhancement of overall functional capacity. Lower-extremity weakness in older adults is a primary independent contributor to reduced walking speed (43), decreased lower extremity performance and functional impairment (13, 19), falls (44, 45), physical disability (46, 47), and frailty (48). RE has also been associated with improvements in various cardiometabolic risk factors in the absence of weight loss, including (1) decreased LDL-cholesterol (49, 50), decreased triglycerides (49), reductions in blood pressure (51), and increases in HDL-cholesterol (50). Several studies have even documented the superiority of RE over traditional AE for glycemic control and insulin sensitivity among type 2 diabetic adults (52). Therefore, with careful planning, the application of RE among older adults with sarcopenia and weakness is not only feasible for eliciting significant adaptation in both force production capacity and muscular hypertrophy, but is also effective for reducing risk of many sarcopenia-related comorbidities. Increased public health and clinical efforts are therefore needed to encourage the provision of this mode of PA.

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IMPORTANCE OF INTRAMUSCULAR CONNECTIVE TISSUE FOR STRENGTH AND FUNCTION IN ELDERLY

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The connective tissue (extracellular matrix (ECM)) is present in many load bearing structures like bone, cartilage, skeletal muscle, ligaments and tendons. Skeletal muscle contains 5-10% ECM and is crucial for force transmission. Both in young and in elderly individuals it is shown that mechanical loading results in an up-regulation of collagen expression and an increased synthesis of collagen protein that is likely regulated by strain of the fibroblast. The degradation of collagen proteins also rises after exercise, but appears to peak earlier than synthsis. In addition to changes in collagen turnover, exercise also influences cross linking in the tendon structure, and some of these reactions appear faster than structural changes in collagen fibrils. Training increases the cross sectional area of the tendon, and tendons of elderly master athletes are thicker and more dense than in untrained counterparts. In skeletal muscle increased amounts of connective tissue with ageing often represents a relative phenomenon due to loss of contractile musculature, and using active elderly the content of collagen in muscle is unchanged with age. On the other hand, the number of non-enzymatic cross links (advanced glycation end-products (AGE's)) is elevated with age and metabolic disease. Aging is associated with changes in mechanical properties of the ECM and the content of collagen and cross-links, but a large amount of these changes are related to changes in the physical activity level rather than to advanced age per se in elderly individuals.

STRENGTH TRAINING IN REHABILITATION OF STRENGTH AND PHYSICAL FUNCTION IN ELDERLY PATIENTS

Charlotte Suetta

INTRODUCTION

The loss of muscle mass with aging, i.e., sarcopenia, and the concomitant decline in muscle strength have far reaching consequences for the elderly and is associated with an impaired ability to perform tasks of daily living, along with an increased risk of disability and mortality [1]. The loss of muscle mass with age is known to be a multi factorial process but the underlying mechanisms for the development of sarcopenia are still largely unknown and although a decrease in physical activity with aging is partly responsible for the development of sarcopenia, maintenance of activity levels does not appear to completely protect skeletal muscles from age-associated atrophy [2].

The consequences of sarcopenia are aggravated by the fact that the relative proportion and life-expectancy of elderly people is known steadily to increase, and thus also the number of elderly with diseases and disabilities related to aging [3]. Moreover, skeletal muscle disuse due to a higher degree of comorbidity and hospitalisation [3], results in a rapid and accelerated loss of skeletal muscle mass *per se* [4]. In fact, immobilisation due to major surgery and hospitalisation markedly increases the risk of deterioration in muscle function leading to disability, especially in frail elderly individuals [5]. In addition, recovery of losses in muscle mass and muscle strength is often very slow [6] and many elderly patients fail to regain the level of function they had before admission to the hospital [7]. Attempts to counteract the muscle atrophy associated with surgery and hospitalisation in the elderly hence seem highly relevant.

Progressive resistance training has consistently been shown to counteract many of the age-related physiological changes in both healthy elderly individuals [8] in frail home-dwelling elderly and in nursing home residents [9]. Muscle weakness and atrophy are probably the most functionally relevant and reversible parameters related to exercise in the elderly population. Importantly, only overloading of muscle with weight lifting exercises has been shown to counteract the loss of muscle mass and strength observed with aging. Klitgaard and colleagues found that elderly endurance trained men had similar muscle size and strength as sedentary individuals, whereas elderly individuals who had performed weightlifting for 12-17 years had similar maximal isometric torques, speed of movements, muscle cross-sectional areas and specific tensions as those of a young control group [2]. Moreover, especially in frail elderly it seems like gains in strength after strength training is robustly associated with improvements in functional parameters such as gait speed, ability to rise from a chair and stair climbing performance [9]. The principles of specificity of the training intervention that apply to younger adults are of equal relevance in the elderly. Consequently, the increase in muscle strength observed with strength training is more dependent on the intensity of the stimulus than age, gender or health status of the individual. In general, increases in muscle mass, strength and power are seen following high intensity progressive resistance training (70-80% of the one repetition maximum), whereas lower intensity regimens result in little, if any, significant gains in strength [10].

Furthermore, an abundance of data demonstrate that strength training also induce neuromuscular changes in healthy elderly indiduals [11] as well as postoperative patients [12]. The very convincing increases in RFD and neural drive showed by Häkkinen and coworkers, have been demonstrated as a result of combined power/strength training performed for both shorter (12 weeks) and longer training periods (21-26 weeks) [11,13,14]. In line with these results, strength training has been shown to improve muscle power in healthy old women [15] as well as in frail old women after a fall [16]. The trainability of both muscle power and rate of force development seems of great importance since both parameters are more affected by aging [17] and furthermore relates more to functional performance in older people than does maximal muscle strength [17].

Progressive strength training has also been shown effective in increasing muscle strength, balance and functional capacity in frail patients shortly after discharge due to acute medical illness [18] and in frail geriatric patients with a history of injurious falls [19]. Moreover, there is accumulating evidence that patients with chronic diseases, such as arthritis [20], diabetes [21], congestive heart failure [22], osteoporosis [23] and chronic obstructive lung disease [24] respond favourably to strength training. The effect may not be due to a positive impact on the underlying disease *per se* as much as to counteract the effects of the disease-related inactivity.

CONCLUSION

It is evident that elderly muscles respond very well to intensive strength training and consequently, this type of intervention should be recognized as one of the key factors in the rehabilitation of elderly individuals. Furthermore, there is increasing evidence that strength training can counteract the decline in muscle function and loss of muscle mass normally associated with hospitalisation in elderly patients. Importantly, both when initiated during the hospital stay, including the acute post-operative phase and after discharge. Additionally, the observation that explosive muscle force capacity of the neuromuscular system remains trainable in elderly recovering from surgery may have important implications for future rehabilitation programs, especially when considering the importance of explosive muscle force capacity on postural balance, maximal walking speed and other tasks of daily life actions.

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COMBINED STRENGTH AND POWER TRAINING FOR OPTIMAL PERFORMANCE GAINS: A BIOMECHANICAL APPROACH

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High velocity of takeoff, release or impact is the primary outcome dictating performance in a wide range of sports requiring sprinting, jumping, throwing, kicking or striking. The physiological, neural and biomechanical mechanisms which combine to produce large impulse are as fascinating as they are complex. The optimal development of these mechanisms through appropriate training requires intelligent and methodical application of current scientific knowledge combined with the skills and insights of the coach and athlete to peak performance for critical competitions while maximising resilience and career longevity. In this paper we will discuss what we believe to be the most impactful mechanisms underlying very powerful human movement and provide insight into training program design so as to optimise strength and power qualities with greatest training efficiency while realistically accommodating time constraints and recovery requirements of the modern elite athlete.

Neural Factors

Neural factors which contribute to high rates of force development as well as high peak force include motor unit recruitment, rate coding, rate of onset of activation, preferential recruitment of fast twitch motor units, and burst synchronous activation[1]. Neural adaptations specific to training occur relatively rapidly within 2 to 4 weeks. However this is a double edged sword as adaptations which negatively impact strength and power occur in a similarly short time frame in response to detraining and/or incongruent training such as endurance exercise which results in conflicting adaptations actually depressing strength and power.

Muscle and Tendon Architecture

Force generating capacity of muscle is proportional to the cross-sectional area while range and velocity of shortening is related to muscle length. Therefore changes to the architecture of muscle resulting from differential training modalities results in alteration in the characteristics of force generation, the length tension relationship, and force velocity relationship. For pennate muscles the additional factor of angle at which the fascicles align with the tendon also contributes to force generation characteristics. Increased pennation angle provides greater force generation while lower pennation angles favour faster contraction velocities. Muscle architecture is highly trainable with heavy resistance training resulting in changes favouring high force production while training with high velocity movements results in adaptation toward faster movement velocities[1].

Intramuscular Factors

Muscle tissue responds to training stimuli with alteration in the fibre expression and enzyme concentrations which is highly specific to the load, volume and speed of movement. Such changes can occur quite rapidly and with only a few exposures[1].

Stretch Shortening Cycle

Almost all human movement for which the intention is to maximise efficiency or impulse applied, involves a counter movement performed prior to the acceleration of the body or its parts in the desired direction of motion. This has been termed the stretch shortening cycle and encapsulates all of the neural, physiological and mechanical mechanisms that we have been discussing. It has long been known that the prior countermovement or stretch phase facilitates the subsequent concentric or shortening phase by around 10 to 15% in terms of the net impulse. This is due to five principal mechanisms which facilitate the positive acceleration phase[2]. While there is much debate over their relative contribution, all appear to play a role and so are important to understand if we are to maximise training outcomes[3].

1) The first is the *preload* that the muscle and tendon are under from the very initiation of the concentric phase. During concentric only movements, the muscles start at rest or at best relatively low levels of activation and active tension. This results in the initial phase of the concentric action to be at relatively low force, certainly below the maximum contraction capacity of the muscle. Thus, the area under the force time curve, the impulse, is smaller and thus the velocity attained at the end of the concentric phase is slower.

Conversely, when a countermovement is performed such as the dip in a vertical jump, force is generated during the eccentric phase and is in fact near maximum around the point of change over from negative to positive movement. This phenomenon is termed preload and as the force at the very start of the concentric phase is already at a high level, the area under the curve or impulse is large and the resulting velocity is much higher[2].

2) The second mechanism relates to the *interaction of the muscle and tendon* during stretch shortening cycle movement. During such movements there is a complex interaction between the muscle and tendon and the forces being exerted externally on this system due to the load which must be moved and any accelerations or decelerations this load is undergoing. When the counter movement is initiated the agonists relax and undergo passive lengthening as gravity and/or antagonist contraction accelerates the system. As there is little tension in the agonist musculotendinous unit (MTU) during this phase the tendon returns to resting length. Toward the end of this phase the agonist muscle is maximally activated and initially undergoes eccentric and then isometric contraction and so can generate high force. Due to the momentum developed in the negative direction, movement continues but with rapidly decreasing velocity as the system is under a strong braking influence of the agonists. During this phase the majority of lengthening of the MTU is occurring in the tendon at it stretches under quite high tensile forces. This primes the MTU such that it is in an ideal state to maximise force and impulse during the subsequent concentric phase. As tension builds in the agonist MTU the system experiences a high positive acceleration which quickly slows, stops and reverses the direction of movement. Once this reversal has occurred the MTU is now shortening with the majority of length change occurring in the tendon as it recoils after being stretched. This mechanism is highly advantageous to the contractile component of the muscle maintaining high force for three reasons. First, the muscle maintains quasi-isometric contraction during which it is undergoing minimal changes in length which allow it to maintain higher tension than if it was shortening. Second, the contractile component is in a lengthened position and remains so for a greater proportion of the concentric phase thus facilitating contraction force production according to the length tension effect. Third, once the muscle has transitioned to a shortening contraction the velocity of length change does not increase as rapidly due to the proportion of overall MTU shortening achieved through tendon elastic recoil. Due to the force velocity relationship for muscle, higher contraction force can be maintained. The overall result is a much higher net impulse during the concentric phase and thus velocity of takeoff, impact or release.

3) Force generation during stretch shortening cycle movements is also enhanced by the *storage and recovery of elastic potential energy*. During the high force stretching of the MTU described above elastic potential energy is stored in the series and parallel elastic elements. The series elastic element consists of the tendon and the intrinsic elasticity of the myofilaments while parallel elastic element consists of the connective tissues that surround the muscle and its fascicles[2].

4) During rapid lengthening of the MTU the *stretch reflex* is activated and through a spinal loop, neural impulses are fed back to overlay the voluntary activation of the muscle resulting in greater contractile force[2].

5) It is also possible that the pre-stretching of the contractile element causes a *potentiation* of their ability to generate force by altering the properties of the contractile machinery. The effect is greater with increased speed of stretch and decreasing with time elapsed after the pre-stretch[2].

The Strength Threshold

It is inherent in the contractile element of muscle that mechanical power output is maximised when shortening velocity is approximately 1/3 of maximal or alternatively against a load which is one third of the force capacity of that muscle during a maximal isometric contraction[4]. Therefore, the higher the maximal strength in a particular movement, the greater the power output and therefore velocity of takeoff, impact or release. Ideally maximal strength should be three times the load which must be accelerated if power is to be maximised. For example, during vertical jump the athlete should have the capacity to back squat more than two times bodyweight if they are to optimise their strength for vertical jump performance.

Strength or Power Training

A long-standing quandary for strength and conditioning specialists has been whether it is more efficacious to prescribe strength or power training for the development of performance in activities such as jumping and sprinting. We recently completed a study comparing heavy back squat with light load jump squats with relatively weak (1RM squat of 1.3 BW) athletes and determined that either intervention resulted in similar improvement (Figure 1)[5]. This is because relatively untrained individuals respond to a wide range of stimuli

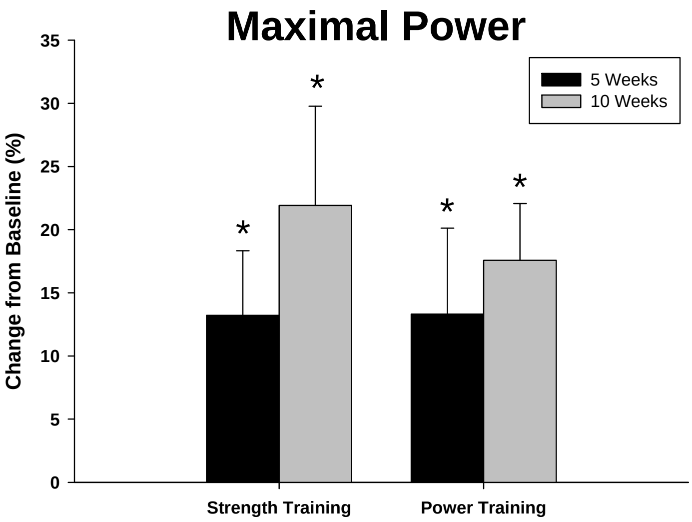

Figure 1. Changes in maximal power during jump squat resulting from either strength or power training.

and in this case both training modes result in neuromuscular adaptations conducive to improved power output.

In a subsequent study[6] we compared relatively strong (1RM squat of 1.9 BW) and less strong (1RM squat of 1.32 BW) athletes completing the same power training program. We found that the stronger athletes could realise a much larger improvement in power production supporting the hypothesis that for long term athlete development it is more effective to attain a high level of strength prior to implementing power type training. When we examined the mechanisms underlying adaptation to power training by strong compared to less strong athletes we discovered that strong athletes are much better able to utilise the eccentric phase of stretch shortening cycle movements as they can tolerate much higher forces and so are better able to maximise the potentiating mechanisms outlined above (Figure 2).

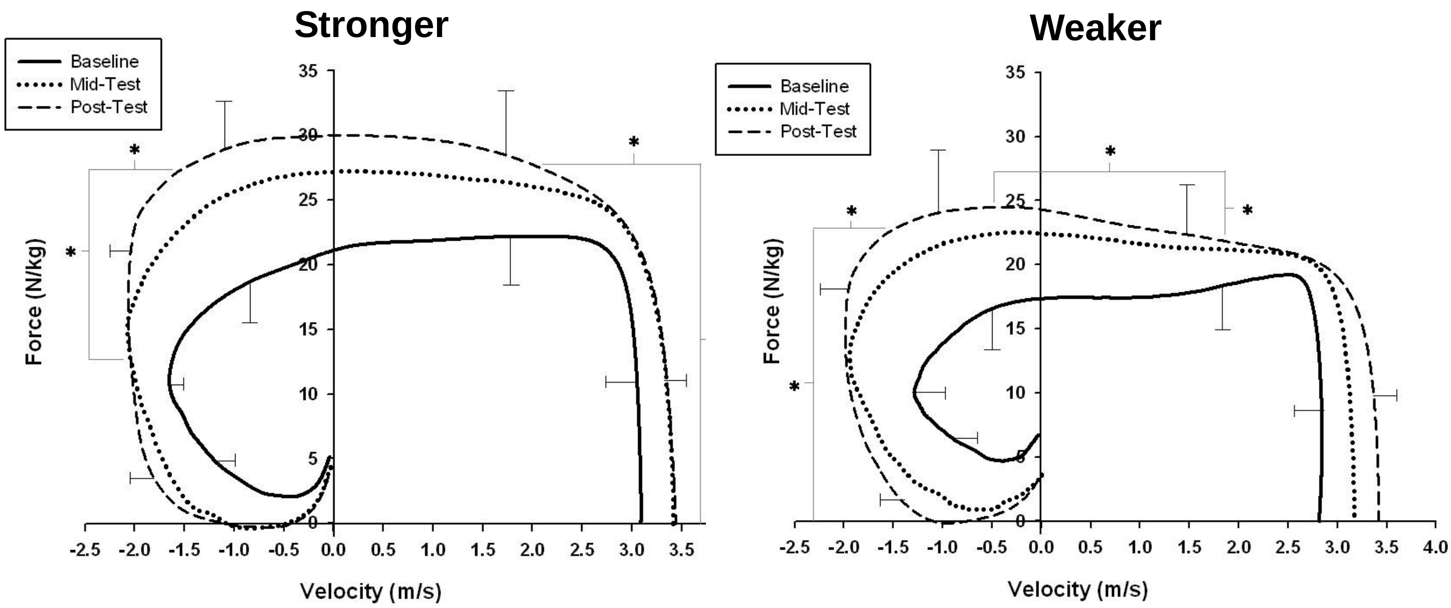

Figure 2. Stronger and weaker athletes exhibit different adaptations in force velocity profiles during jump squats in response to power training.

Muscle and Tendon Characteristics

Recently our team has been investigating the interaction of muscle and tendon during various heavy resistance, ballistic and accentuated stretch load (depth jump) activities. An interesting outcome with high relevance to athletic training and performance is the finding that tendon behaviour changes dependent on the loading characteristics. Under certain thresholds of force and rate of force application the tendon is quite elastic however if the force transmitted through the tendon is high and/or the rate of increase in force is rapid the mechanical properties alter such that it becomes much stiffer and resists stretching. During ballistic movements when the intention is to accelerate as fast as possible, such as the rapid knee extension under load, we have observed that the tendon of the knee extensors behaves as a “power amplifier” up to a point but changes to become a rigid “force transducer” at heavy loads(Figure 3). This has implication for training as it would appear beneficial if the mechanical characteristics of the tendon could be altered such that the power amplification role was maintained at higher loads. We subsequently completed a longitudinal training study comparing traditional heavy resistance training in the form of back squats with lighter load jump squats and depth jumps. As expected quite specific changes occurred in the muscle and tendon structure as well as various performance characteristics of strength and power. This was particularly interesting as only the heavy resistance training caused any alteration in tendon characteristics which was increased stiffness (Figure 4).

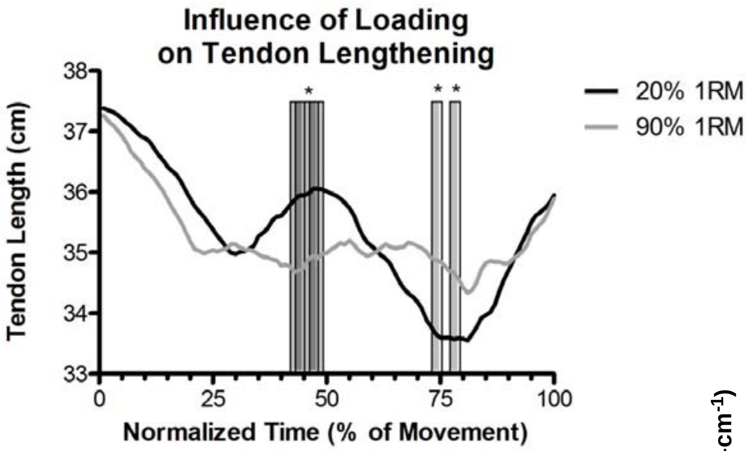

Figure 3. Influence of loading on tendon length (L_t) throughout a stretch shortening cycle knee extension. Time is depicted as relative to the completion of the movement. Significant differences between loads ($p < 0.05$) are depicted by dark shading and non-significant trends ($p = 0.053$-0.075) are depicted by light shading.

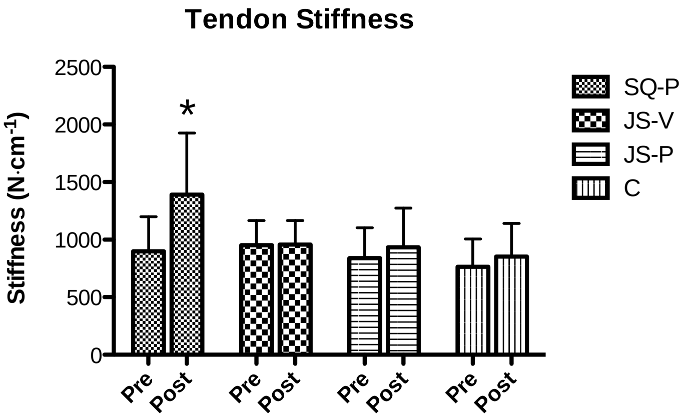

Figure 4. Quadriceps tendon stiffness adaptations in response to 8-weeks of parallel depth squat training (SQ-P), jump squat training performed with volitional depth (JS-V) and parallel depth (JS-P) or no training (C). * indicates a significant increase in response to training.

CONCLUSIONS

Performance of highly spectacular human movement as exhibited in sports requiring very high force, velocity and power involves highly complex interactions of physiological, neural and mechanical phenomena. Developing strength and power through physical training requires solid understanding of these mechanisms so as to maximise efficiency in the face of limited athlete time availability. The stretch shortening cycle is the basis of almost all human movement and the underlying qualities that dictate the performance outcome can be finely manipulated through specific training. While relatively weak individuals will respond to strength or power training with similarly improved performance, strong athletes are better able to glean performance improvements from power training principally through more effective utilisation of the eccentric phase. Tendon has a very important role to play in movement and the mechanical properties can also be altered through training. Considered as a whole it appears that a relatively high level of maximal strength is the most influential quality of the neuromuscular system.

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THE USE OF INSTABILITY RESISTANCE TRAINING FOR HEALTH AND PERFORMANCE

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While the popularity of instability resistance training is evident in fitness training facilities, its effectiveness for optimal athletic training has been questioned. Instability resistance exercises have become a popular means of training the core and improving balance. Whether instability resistance training is as, more, or less effective than traditional ground based resistance training is not fully resolved. The purpose of this presentation is to explore the instability literature to determine the suitability of IRT for athletic performance and health.

Balance training studies typically less than 10 weeks have shown dramatic improvements (average of approximately 100%) in postural stability. The ability to stabilize the core or trunk region is vital in the transfer of torques and momentum to the limbs. Improving balance or stability can improve functional performance even without resistance training. Balance training studies that examine improvements in functional performance can typically show improvements of more than 20%. The logical progression would be to add resistance to a balance-training program.

The criticism of instability resistance training for athletic conditioning is based on the findings of impaired kinetic measures such as force, power and movement velocity. However, these deficits occur with minimal changes or in some cases increases in trunk and limb muscle activation. Compared to the instability-induced kinetic deficits, the relatively greater trunk muscle activation indicates a greater stabilizing function for the muscles. While, the lower external forces exert less, but healthy stress on a more injury-susceptible joint, the less dramatic changes or even increases in trunk and limb muscle activation provide greater stabilizing functions to protect recovering muscles and articulations. Greater coordination training challenges with instability exercises should promote motor control adaptations (i.e. co-activations, anticipatory postural adjustments) that are especially important with low back pain maladjustments.

Training programs must prepare athletes for a wide variety of postures and external forces and should include exercises with a destabilizing component. While unstable devices have been shown to be effective in decreasing the incidence of low back pain and increasing the sensory efficiency of soft tissues, they are not recommended as the primary exercises for hypertrophy, absolute strength, or power especially in trained athletes. For athletes, ground based free weight exercises with moderate levels of instability should form the foundation of exercises to train the core musculature. Instability resistance exercises can play an important role in periodization, rehabilitation and as alternative exercises for the recreationally active individual with less interest or access to ground based free weight exercises.

REVEALING "SECRETS" OF STRENGTH TRAINING EXERCISES WITH KINETIC ANALYSES

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INTRODUCTION

The bench press exercise is likely the most used exercise to develop upper body strength among competitive athletes at all levels. It has been show a good relationship between the 1RM bench press and sport specific performance in a wide range of sports (Burnham et al., 2010; Chelly et al., 2010; Crossland et al., 2011; Hermassi et al., 2011; Marques et al., 2007; Terzis et al., 2012)
In most gyms around the world, there is a great likelyhood that the bench press is in use among recreational athletes. The exercise is relatively simple and can be done without too much prior experience. Part of the reason for the popularity is the fact that the bench press exercise is often seen as THE exercise for developing impressive upper body muscles and as to measurine the strength.

Due to its popularity, the exercise has been thoroughly investigated with respect to e.g. how training methods (Brennecke et al., 2009; Ghigiarelli et al., 2009; Hermassi et al., 2011; Miranda et al., 2011; Prestes et al., 2009), anthropometrics (Caruso et al., 2012), supplementation (del et al., 2012; Duncan and Oxford, 2011; Zuniga et al., 2012), use of special equipment (Baker and Newton, 2009; Burnham et al., 2010; Marin et al., 2011; McCurdy et al., 2009; Silver et al., 2009) can improve the performance. When making a Pubmed search for "bench press" a total of 826 hits were obtained. More than half were published during the last 5 years. Several reports have been written about related injuries (Hasegawa and Schofer, 2010; Kindt et al., 2010; Provencher et al., 2010). Also technique variables have been investigated, e.g. muscle activation patterns (Brennecke et al., 2009; Goodman et al., 2008; Kohler et al., 2010; Martins et al., 2008; Saeterbakken and Fimland, 2012; Santana et al., 2007; Trebs et al., 2010; van den Tillaar and Saetersbakken, 2011), kinematics of the lift (Krol et al., 2010; Madsen and McLaughlin, 1984; Pearson et al., 2009; van den Tillaar and Ettema, 2009; van den Tillaar and Ettema, 2010), including the "sticking point" (van den Tillaar and Ettema, 2009; van den Tillaar and Ettema, 2010; van den Tillaar and Saetersbakken, 2011). Several studies have investigated the effect of lifting using unstable surfaces (Kohler et al., 2010; Saeterbakken and Fimland, 2012; Uribe et al., 2010). Different modes of the exercise such as using e.g. dumbbells, barbell, or restricting the bar to a one degree-of-freedom movement have also been studied with respect to the above mentioned variables (Cotterman et al., 2005; Santana et al., 2007; Schick et al., 2010; van den Tillaar and Saetersbakken, 2011).

RESEACH QUESTIONS

Despite the extensive research and the enormeous popularity, there are still many unanswered questions related to the bench press exercise. Some of the key questions are related to performance and muscle activation patterns in various forms of the exercise, such as:

- Why can we lift more using a barbell compared with dumbells?
- Why do we see different muscle activation patterns between barbell and dumbbell bench presses although the kinematics is perfectly similar?

DISCUSSION

In a recent study from van den Tillar and Saeterbakken (2011), it was shown that a group of male students could lift substantially heavier loads using a barbell compared with dumbbells. It was hypothesized that this could originate from the need for greater stabilization in the dumbbell exercise. However, although balance/stability is an obvious limiting factor for a novice, a more experienced athlete will generally not experience stability problem performing the exercise.

In order to understand the difference between barbell and dumbell lifting, a kinetic analysis of the exercise is necessary. In such analys it is necessary to understand the difference in mechanics between the two modes. When considering Fig 1 below, it is clear that while the dumbell press represents an “open chain” system, the barbell press represent a “closed chain” system.

AB

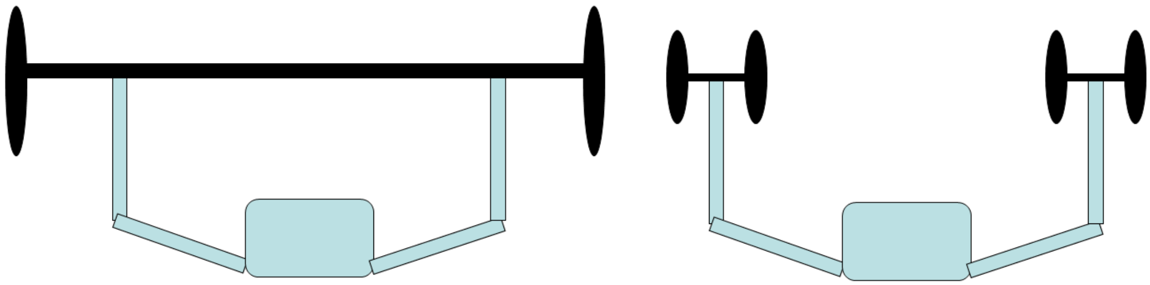

Fig 1. (A) Open kinetic chain exercise (The dumbbell press) and (B) Closed kinetic chain exercise (The barbell press)

The difference between these to systems becomes obvious when considering the contact external forces. In the open chain situation, the external contact forces that are transmitted through the hands will obviously point directly down due to gravity. On the closed chain system, on the other hand, the forces will normally also have a medio-lateral component due to friction, especially with a wide grip. This was shown by Duffey and Challis (2011) who measured the lateral forces on the bar to be apx 25% of the vertical forces throughout the range of movement.

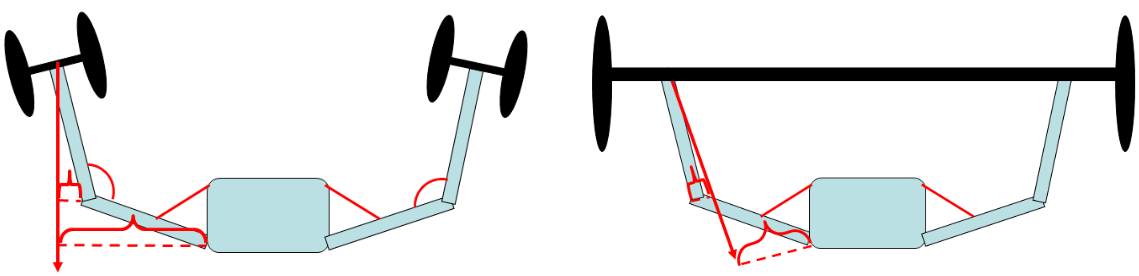

Fig 2. (A) Vertical forces giving an external elbow extension moment (biceps activity necessary) and large moment arm to the shoulder joint. (B) A more medial directed external force giving an external elbow flexion moment (triceps activity necessary) and a smaller moment arm to the shoulder

CONCLUSION

As a consequence, the triceps will be more involved when using the barbell, and the moment arm to the shoulder joint will be reduced compared with the dumbbell press (Fig 2). Both of these factors will contribute to increased lifting performance in barbell bench press as compared with dumbbell presses.

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OPTIMISING MUSCLE MASS THROUGH EXERCISE AND NUTRIENT AVAILABILITY

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INTRODUCTION

Skeletal muscle displays remarkable plasticity enabling substantial adaptive modifications in its metabolic potential and functional characteristics in response to external stimuli such as mechanical loading (i.e., resistance training) and macronutrient availability (i.e., protein feeding). In simplistic terms, the process of exercise- induced adaptation in muscle can be viewed as the consequence of the accumulation of specific proteins, with the gene expression promoting an increase in protein concentration pivotal to any training-induced response (Hansen et al. 2005). The functional consequences of contraction-induced adaptations are determined largely by the mode of training (i.e., endurance- versus resistance-based) and the volume, intensity and frequency of this stimulus (Hawley 2002). Ultimately, however, the ability of a given muscle cell to alter the type and quantity of protein is a function of its half-life; proteins that turn over rapidly and have high rates of synthesis are capable of attaining a new steady-state level faster than those that turn over slowly during adaptation to contractile and other stimuli.

Several recent studies from our lab clearly demonstrate that nutrient availability can serve as a potent modulator of many acute responses and chronic adaptations to both endurance-based (Yeo et al. 2008; Yeo et al. 2010) and resistance-based exercise training (Camera et al. 2012; Churchley et al. 2007). This is not surprising given that changes in macronutrient intake rapidly alter the concentration of blood-borne substrates and hormones and cause marked perturbations in the storage profile of skeletal muscle and other insulin-sensitive tissues. In turn, muscle energy status exerts profound effects on resting fuel metabolism and patterns of fuel utilization during exercise as well as acute regulatory processes underlying gene expression and cell signalling (for review see Hawley et al. 2011). As such, these nutrient-exercise interactions have the potential to activate or inhibit many biochemical pathways with putative roles in training adaptation.

The anabolic effects of resistance-based exercise on skeletal muscle are well established (Coffey & Hawley 2007). However, little is known regarding the effects of altered energy availability on the acute protein synthetic response to resistance exercise and whether the summation of these responses may promote or attenuate training-induced adaptation. This is an important area of research because a constant challenge for the majority of competitive athletes and sedentary individuals alike is how to reduce fat mass (FM) while simultaneously preserving or increasing fat free mass (FFM) through the manipulation of physical activity (i.e., training load) and energy availability (i.e., energy restriction). Although it has been recommended that that athletes who wish to gain FFM and increase maximal strength during a period of energy restriction should aim for small weekly losses in body mass (Garthe et al. 2011), there is a paucity of information on the effects of altering energy availability on body composition and skeletal muscle protein turnover (i.e. the balance between protein synthetic and catabolic processes).

RESULTS/DISCUSSION

Pasiakos et al. (2010) determined rates of skeletal muscle protein synthesis (MPS) and intracellular signalling events in response to either 10 days of energy balance or 10 days of moderate energy deficit (~80% of estimated energy requirements) in physically active (but not athletically trained) adults. Dietary protein (1.5 g/kg body mass (BM)/day) and fat intake (~30% of total energy) were similar for both interventions. Compared to energy balance, subjects lost a small amount of BM (~1 kg) after 10 days of energy deficit. Basal rates of MPS were reduced 19% ($P<0.05$) while the phosphorylation state of selected synthetic intracellular signalling proteins were also lower in response to acute energy restriction. While the results of this study are of interest to sedentary individuals attempting to lose 'weight', it is unclear how they can be applied to athletic populations, especially strength-trained athletes who are likely to be undertaking strenuous daily training sessions with appropriate nutritional recovery strategies (i.e., post-exercise protein supplementation). Indeed, as there are synergistic effects of protein availability and contractile activity on MPS which act to promote positive net protein balance in muscle, it would seem prudent to determine if rates of MPS can be conserved in resistance trained athletes during periods of planned energy restriction, thereby preventing a loss of FFM. Accordingly, we are currently investigating the dose response characteristics of MPS following resistance exercise followed by the immediate intake of different amounts of protein in male and female athletes from strength and/or power-based sports during short periods (5-7 days) of low energy availability. A safe and practical weight loss situation has been created in which energy availability is clamped at 30 kcal/kg FFM, an amount that allows a total daily energy deficit of 500-750 kcal, while simultaneously minimising the potentially deleterious effects of hormonal and metabolic perturbations on bone mass. While the optimal dose of protein for ingestion by athletes in energy balance is around 20-25 g of protein (8-10 g of essential amino acids) immediately post exercise (Moore et al. 2009), we hypothesise that during periods of energy restriction, athletes will require a higher dose along with more frequent protein feedings throughout the day to conserve MPS and maintain FFM while concomitantly reducing FM.

While whole-body energy availability is important for ‘fine-tuning’ body composition in athletes competing in weight-bearing sports, we have recently determined the effect of skeletal muscle energy status and post-exercise energy availability on anabolic signalling and rates of MPS after a single bout of resistance exercise in strength-trained males (Camera et al. 2012). After 48 hr of standardised diet and exercise, subjects undertook a glycogen-depletion protocol consisting of one-leg cycling to fatigue (LOW), whereas the other leg rested (NORM). The next day following an overnight fast, a primed, constant infusion of l-[ring-$^{13}C_6$] phenylalanine was commenced and subjects completed 8 sets of 5 unilateral leg press repetitions at 80% of 1RM. Immediately after the resistance exercise bout and then again 2 hr later, subjects consumed a 500 mL of a protein-carbohydrate beverage containing 20 g whey plus 40 g of maltodextrin or a coloured, flavoured placebo beverage. Muscle biopsies from the *vastus lateralis* of both legs were taken at rest and 1 and 4 hr after resistance exercise. As intended, muscle glycogen concentration was higher in the NORM than LOW at all time points in both nutrient and placebo groups ($P < 0.05$). Post-exercise Akt-p70S6K-rpS6 phosphorylation increased in both groups ($P < 0.05$) with no differences between legs. mTOR(Ser2448) phosphorylation in placebo increased 1 h after exercise in NORM ($P < 0.05$), whereas mTOR increased ~4-fold in LOW ($P<0.01$) and ~11 fold in NORM with nutrient ($P<0.01$; different between legs $P < 0.05$).

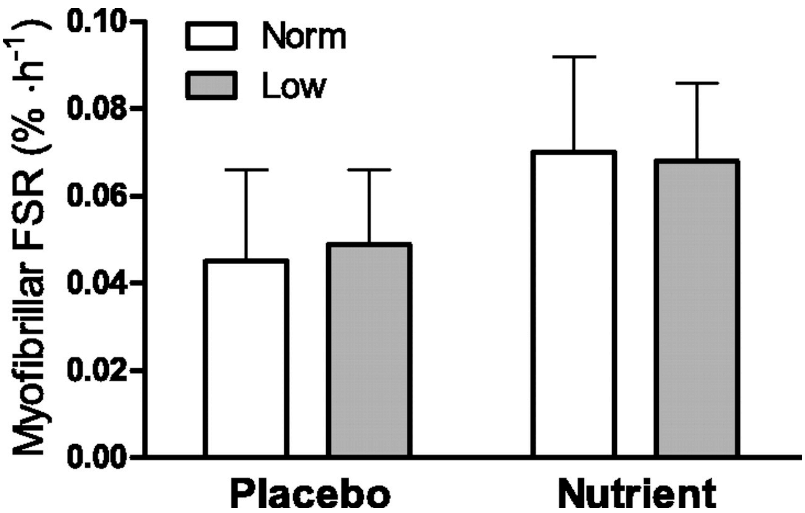

Figure 1. Myofibrillar protein fractional synthetic rate (FSR) during 4 hours of recovery after a single bout of resistance exercise (8 × 5 leg unilateral leg press at ~80% of 1RM) and ingestion of either 500 mL placebo or nutrient beverage immediately post and after 2 hr of recovery in subjects with either normal (NORM) or low (LOW) muscle glycogen availability. Values are means ± SD. Data are from Camera et al. (2012).

In contrast to our previous work showing that low glycogen availability enhanced the acute responses (Yeo et al. 2010) and chronic adaptations (Yeo et al. 2008) associated with an endurance-based phenotype, it appears that modulating muscle glycogen availability has little effect on the rates of MPS and selected signalling responses during early recovery from a bout of resistance exercise.

CONCLUSION

A constant challenge for competitive athletes and the overwhelming majority of sedentary individuals in Western nations is how to reduce FM while simultaneously preserving (or increasing) FFM. These twin goals are not mutually exclusive but can be attained through the systematic manipulation of physical activity (i.e., training load) and energy availability (i.e., energy restriction). In particular, it has emerged that a high protein intake during periods of low energy availability maintains FFM relative to total BM loss, which in turn enhances physical capacity (i.e., training output and/or functional outcome measures of daily living). We have provided novel information on which to base future investigations aimed at optimising the metabolic conditions necessary to positively influence the cellular mechanisms specific to skeletal-muscle protein turnover during periods of low energy availability.

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PROTEIN SUPPLEMENTATION AND RESISTANCE EXERCISE IN DETERMINATION OF HYPERTROPHY

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INTRODUCTION

The fundamental basis of resistance exercise-induced skeletal muscle hypertrophy is an enlargement of the protein pool within a muscle fibre. This requires the convergence of two processes: positive protein balance and appropriately timed activation, proliferation, and fusion of satellite cells. Our lab has developed methods to measure the acute changes in muscle protein synthesis (MPS) and muscle protein breakdown (MPB) with the understanding that a positive muscle protein balance requires MPS being greater than MPB. Our current understanding is that MPS is stimulated by both protein feeding and resistance exercise independently and that the two stimuli together result in a synergistic stimulation of MPS (3, 15). In normal healthy young men the fluctuations in MPS and at least 4-times those seen in MPB. Thus, strategies to enhance positive protein balance would be best targeted at a stimulation of MPS.

Temporally, the majority of evidence shows that in the post-exercise is the optimal time period for protein ingestion to synergistically stimulate MPS (2, 7). The reason for the post-exercise period being the optimal time for stimulation of MPS is that resistance exercise activates a number of signalling pathways that make muscle sensitive to hyperaminoacidemia (16). Of the amino acids it is only the essential amino acids that are required for MPS (21), with the branched-chain amino acid leucine being of central importance in stimulating the centrally important protein in MPS (14), the mammalian target of rapamycin (mTOR) (12,

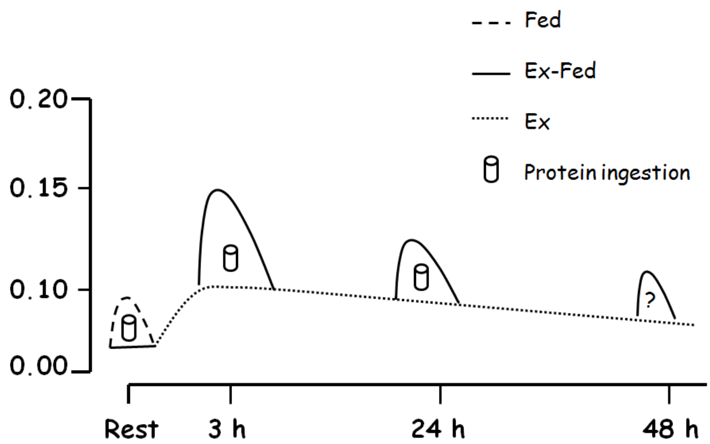

Figure1. Resistance exercise stimulates a prolonged elevation of muscle protein synthesis (MPS) that can remain elevated for ≥ 24 h (dashed lines). Thus, we propose that protein ingestion at any point during this enhanced period of 'anabolic potential' will be additive to these already elevated exercise mediated rates (solid line). Fed – protein feeding, Ex – resistance exercise. From reference (7).

16) In addition, recent evidence suggests that amino acid transport, in particular the leucine transport protein LAT1, may be important in signalling to mTOR and triggering MPS (6). In fact, we have reported that a single bout of resistance exercise can sensitize the muscle to hyperaminoacidemia for up to 24h post-exercise (4) (Figure 1) an effect that may be due to enhanced LAT1 membrane-embedded transporter content and/or intrinsic activity. Thus, the leucine content of a protein appears to be critically important in determining the protein's ability to stimulate MPS (6, 20).

RESULTS & DISCUSSION

We have reported that milk proteins are superior to soy proteins in stimulating MPS (23) and this difference was shown to translate into differential hypertrophy between milk and soy-supplemented young men during resistance training (8). We also showed that young women exhibited a substantial hypertrophy (as well as fat loss) when supplemented with milk versus carbohydrate (11). When we compared milk's two main protein components, casein and whey, we found that whey was superior to casein and isolated soy protein in

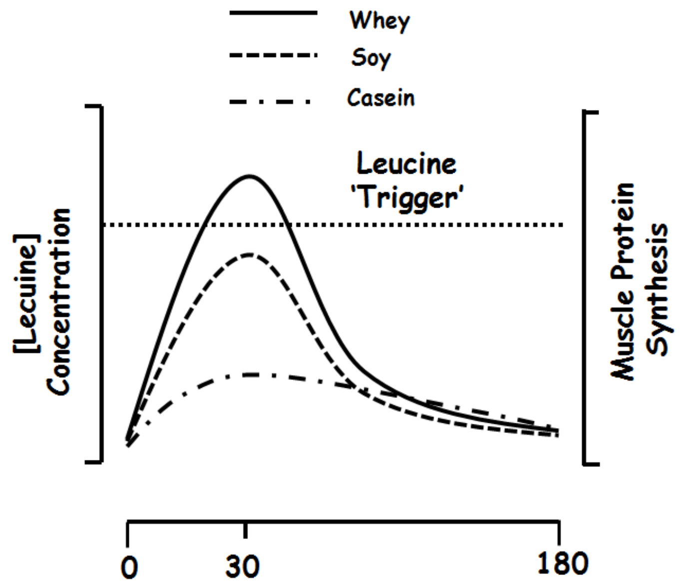

Figure 2. The 'leucine trigger' concept with data adapted from (Tang et al., 2009) as shown for whey protein, soy protein, and casein proteins. These rapidity of digestion of these proteins would be in the following order whey > soy >> casein, and the following leucine content whey > casein > soy. Thus, a greater and more rapid rise in blood leucine triggers a greater rise in MPS.

stimulating MPS (20). We have found the same in older persons (5). These results are largely predictable based on the rate of digestion of the protein meal and also the leucine content of the protein. We are confident that rapidly digested, high-leucine containing protein provide the most potent stimulus for MPS. This has lead us to propose the leucine trigger hypothesis which is shown schematically in Figure 2.

To date, few compounds have been shown to stimulate MPS more than protein and resistance exercise. We have tested large doses of glutamine (0.3g/kg) (22), arginine (10g) (19), high carbohydrate (50g) (18) and none were able to augment the impact of an optimally potent (for MPS) dose of protein (~20-25g) or essential amino acids (8-9g) (13). This optimal dose of protein translates into a dose of somewhere between 0.25-0.3g protein/kg/meal of high quality protein and we have advocated that on a per meal basis this would be an optimal dose to consume (2) to stimulate MPS. It would also be prudent to consume this dose of protein at meals spaced regularly throughout the day and to make sure that there was a good leucine content of this meal. In fact, the leucine content of a meal has been shown to be an important predictor of the post-meal MPS response (14). It also now appears that prior to bedtime would be a prudent time to consume some protein to promote overnight MPS during the time when most of us likely go for the longest time period without eating (17). For an athlete seeking to recover from and recondition muscle and/or promote hypertrophy this may be a highly beneficial practice to allow recovery to take place.

Combining our knowledge of leucine's potent ability to stimulate MPS and also meal timing we designed a weight loss trial in which we had women consume a higher dairy protein and carbohydrate restricted hypocaloric diet. Women consuming this diet showed greater fat loss, abdominal fat loss, and muscle gain during 16wk of a 750kcal/d energy deficit induced by diet (500kcal/d) and physical activity (250kcal/d) (9). An additional advantage of this dietary pattern during weight loss was the beneficial change in markers of bone turnover during the 16wk weight loss period indicating a preservation of bone health (10).

CONCLUSIONS

The promotion of MPS occurs through both protein feeding and resistance exercise. High leucine containing proteins, in particular whey protein, would be optimal choice proteins for maximizing MPS. Attempts to augment MPS of an optimally effective dose of protein via the addition of glutamine, arginine, and/or carbohydrate are ineffective. Consumption of protein at a dose of ~0.25-0.3g/kg/meal post-exercise appears to be optimal for young persons to stimulate MPS to optimize anabolism. Regular consumption of protein containing meals throughout the day at 3-4h intervals appears to be an optimal pattern for periodic stimulation of MPS to be maximally active and prevent an aminoacidemia-induced refractory response in MPS (1). Pre-bedtime feeding also appears to be effective in stimulating MPS and would be an optimal time to offset the decrement in MPS and rise in MPB. Finally, during periods of hypocaloric intake athletes are advised to increase their protein intake to ~1.6-1.8g/kg/d and consume high quality dairy-based proteins since these proteins are high in leucine and can spare muscle and improve markers of bone health.

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CHANGES IN BODY COMPOSITION AND PERFORMANCE IN ELITE ATHLETES DURING A PERIOD WITH NEGATIVE ENERGY BALANCE COMBINED WITH STRENGHT TRAINING.

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INTRODUCTION

Weight loss in athletes is generally motivated by a desire to optimize performance by improving power to weight ratio, making weight in order to compete in a certain weight category or due to aesthetic reasons in leanness sports. Due to the negative effects of rapid weight loss and longer periods of restricted energy intake (5,6,12), existing literature recommends a gradual weight loss through moderate energy restriction promoting a weekly weight loss of 0.5-1 kg (3,13). To induce a weight loss of 0.5-1 $kg \cdot week^{-1}$ an energy deficit corresponding to 500-1000 $kcal \cdot day^{-1}$ is needed. This can be achieved by reduced energy intake, increased energy expenditure, or a combination of the two. However, a decrease in body mass due to energy restriction can lead to loss of lean body mass (LBM) (6,7) and thereby impair performance (2,7). Strength training in combination with mild energy restriction can preserve LBM during weight loss periods in overweight sedentary subjects (8). Therefore, to make the weight-loss interventions as effective as possible, we combined energy restriction with strength training to alleviate the expected negative consequences on LBM and performance. Finally, when the weight loss goal is fixed, most athletes choose to use the shortest amount of time to reach the weight goal to avoid extended periods of fatigue. There are probably different implications of reducing daily energy intake by 500 or 1000 $kcal \cdot day^{-1}$, and a reduction of 1000 $kcal \cdot day^{-1}$ can compromise recovery and impair training adaptations in athletes, especially in those with an already low energy intake (1,9).

Consequently, we wanted to compare two practical approaches to the recommended weight-loss regimen in the literature. Thus, we compared a weekly BW loss of 0.7% vs. 1.4% (i.e. twice the relative weight), which corresponds to a weekly weight loss of 0.5 vs. 1 kg respectively, in a 70 kg athlete. We hypothesized that the faster weight loss regimen would result in more detrimental effects on both LBM and strength and power related performance.

RESULTS

Baseline energy intake was, 2409±622 $kcal \cdot day^{-1}$ and 2514±518 $kcal \cdot day^{-1}$ for SR and FR respectively. Energy intake was reduced more in FR (30±4%) than in SR (19±2%) ($p=0.003$) (table 2), according to the aim of faster weight loss. Although intake of most of the macronutrients was significantly reduced, none of the variables differed between groups. Body mass (BM) was reduced by 5.6±0.8% in SR ($p<0.001$) and 5.5±0.7% in FR ($p<0.001$) (Fig 1). The average weekly rate of weight loss for the SR and FR was 0.7±0.4 % and 1.0±0.4%, respectively. In accordance with the aim of the study, the rate of weight loss in FR was significantly faster than in SR ($p=0.02$). FM decreased more in SR than in FR (31±3 vs. 21±0%, respectively, $p=0.02$) (Fig 1). Total LBM increased significantly in SR by 2.1±0.4% ($p<0.001$), whereas it was unchanged in FR (-0.2±0.7%) with significant differences between groups ($p<0.01$) (Fig 1). The increase in total LBM in SR was mainly caused by a 3.1±0.8% increase in upper body LBM. The weekly gain in LBM was 0.3±0.0% vs. 0.0±0.1%, ($p=0.02$) for SR and FR, respectively.

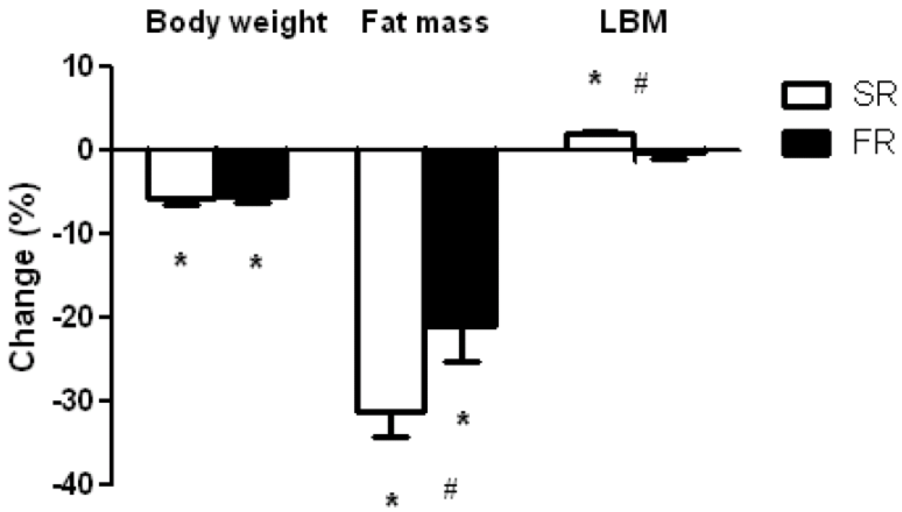

Figure 1. Changes in body weight (BW), fat mass (FM), and lean body mass (LBM) in the slow rate group (SR) and the fast rate group (FR). Data are presented as mean±SE. * $p<0.05$ significantly different from pre, # $p<0.05$ significant difference between groups.

Jumping performance in CMJ was improved by 7±3% ($p<0.01$) in SR, while no significant change was observed in FR (Fig 2). There was no change in 40m sprint performance in any of the groups. 1RM squat improved similarly by 11.9±3.4% ($p<0.01$) in the SR and 8.9±2.3% ($p<0.01$) in the FR (Fig 2). Bench press performance increased more in SR than in FR (13.6±1.1 vs. 6.4±3.3%, respectively, $p=0.01$) (Fig 2). The performance in bench pull was improved by 10.3±3.0% ($p=0.001$) in the SR and 4.0±2.6% in the FR. Overall change in 1RM for the upper body exercises was higher in SR than in FR (11.4±2.6% vs. 5.2±2.4%, respectively, $p=0.03$). The weekly gain in mean relative changes in all 1RM measurements was 1.4±0.7% and 1.3±0.5% for SR and FR, respectively. There were no significant correlations between changes in any of the performance variables, strength training experience, weight loss experience or weekly weight-loss rate and changes in body composition.

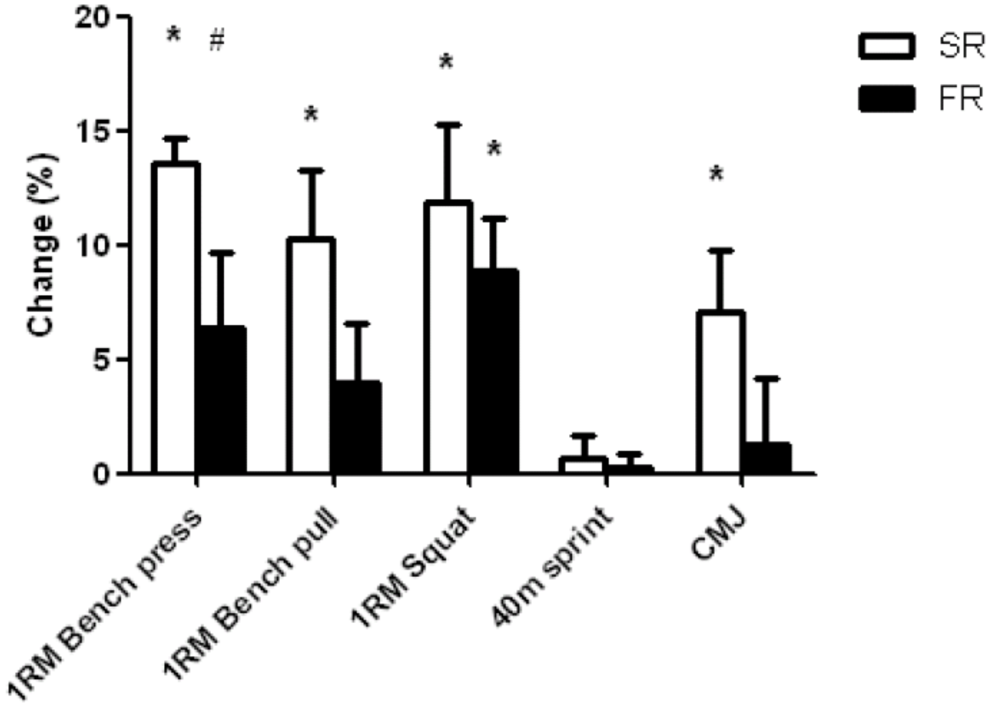

Figure 2. Changes in 1RM bench press, bench pull and squat, counter movement jump (CMJ) and 40m sprint performance in the slow rate group (SR) and the fast rate group (FR). Data are presented as mean±SE. * $p<0.05$ significantly different from pre, # $p<0.05$ significant difference between groups.

DISCUSSION

Studies on gradual weight loss in athletes are sparse, and the methodology is limited due to small sample sizes and different nutritional strategies and measurements of performance and body composition. However, it has been reported that loss of LBM accounts for 30-85% of the total weight loss after reducing body weight by 4-8% (6,10,12). Furthermore, a curvilinear relationship between initial body fat content and the proportion of weight loss consisting of LBM is reported (4). Consequently, weight loss in already lean persons will normally compromise LBM even when incorporating exercise in the weight loss intervention (4). Although some studies support this, especially studies which include endurance exercise as intervention (8), other studies report a different weight loss composition in favour of preserving LBM when heavy strength training is added (8,11). Although the composition of the weight loss varies between studies, most studies report loss of LBM during energy restriction even in obese subjects (4,11,13).

In contrast to the suggested curvilinear relationship between initial body fat content and the proportion of weight loss consisting of LBM, we found no correlations between initial fat mass and changes in LBM. The reason for this may be the heavy strength training during intervention stimulating muscle growth and thereby overriding the catabolic effect of negative energy balance on LBM. In a study by Umeda et al. (12), 38 athletes participated in a 20 day intense training regimen (21 $h \cdot week^{-1}$ exercise, including two $h \cdot week^{-1}$ of strength training) combined with energy restriction. The athletes reduced their BW by 2.8 kg, and loss of fat free mass contributed to 61% of the total weight loss. Although the intervention was of shorter duration, the weekly weight loss rate corresponded to 1.2% of BW, and thus is comparable with the result in the present study. These results suggest that a certain amount of heavy strength training is critical to preserve or increase LBM during energy restriction in elite athletes.

Existing studies are equivocal when it comes to performance, but most weight loss studies report impaired performance (2,7,12). It is a challenge to measure sport specific performance and interpret the results, especially if athletes from more than one sport are included. We included athletes from several sports in this study due to several reasons. Adequate sample size is one of the limiting factors when elite athletes are included in more challenging intervention studies. Further, it was important for us to include all the athletes that request for weight-loss assistance. Because of the heterogeneous group of athletes in this study, we included more general tests of strength and power related performance. Nevertheless, the more general impact on physical capacity measured in this study, gives important information on how function is affected by the interventions.

CONCLUSIONS

The initial aim of two-fold difference in weight-loss rate was not achieved in all the athletes in FR, resulting in a weekly weight-loss rate corresponding to 1.0 % of BW rather than 1.4%. However, total LBM increased significantly more in SR, accompanied by significantly improved performance in CMJ and all the 1RM tests, whereas there was no significant increase in LBM or improvements in performance except in 1RM squat in FR. Separating into weekly gains in LBM and improvements in strength and power related performance, there was a significant difference between groups in favor of SR. This leads to a general suggestion that athletes who want to gain LBM and increase strength and power related performance during a weight loss period combined with strength training, should aim for a weekly weight loss of 0.7% of BW, whereas athletes, who only want to keep LBM, may possibly increase their weekly weight loss rate to 1.0-1.4% of BW.

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RECOVERY AFTER STRENGTH TRAINING

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In order to gain strength and muscle mass, we need to challenge our muscles capacity to generate maximal force. This can be achieved by lifting heavy weights (loads) close to our 1 Repetition maximum (i.e. > 80% of 1 Repetition maximum); in other words, performing traditional heavy load strength training. Alternatively, we can fatigue our muscles by performing a high number of repetitions and sets to a point when also light/low loads (i.e. 20-50% of 1RM) require maximal effort and full recruitment of the motoneuron pools. Training with low loads can effectively be combined with blood flow restriction (BFR) to fatigue the exercising muscles more rapidly.

The basis for inducing muscle growth is activation of certain intracellular signaling pathways in the muscle cells and increased protein synthetic rate. As the protein breakdown rate may change as well, it is the *net* protein synthesis that determines protein accretion. Thus, regularly repeated exercise-induced increases in the net protein synthesis translate into muscle mass gain. We assume that mechanical stress is the major stimulus during heavy load exercise, while metabolic stress (e.g., oxidation) is the major stimulus during low load exercise (10; 13; 24-26).

Increased activity in "hypertrofic signaling pathways" and increased protein synthetic rate occur in the recovery period after each exercise session. The recovery period can be defined as the time period of reduced muscle function after an exercise session. Completed recovery – i.e., normalization of muscle function – typically occurs within 24-72 hours after a bout of traditional strength training (8; 9; 11; 19; 22). Interestingly, exercising with low loads seems generally to induce shorter recovery periods than exercising with heavy loads, even though both modes may be performed to exhaustion (7; 9; 12; 27). The practical implication of this seems to be that low load training (with or without BFR) allows for a high training frequency (e.g. daily exercise of the same muscle (15)).

The mechanisms behind the reduced muscle function after strength training, e.g. reduced maximal force, are not easily deciphered, but reduced force-generation at the cross-bridge level due to metabolites (e.g., P_i) and/or an altered redox-status, impairment in the excitation-contraction coupling, and myofibrillar disruptions are possible culprits (1; 2). Additionally, reduced neural drive to the muscles may also explain some of this muscle function deficit (3). Damage to certain structures and molecules in the "contractile machinery" is an intuitive and easy to understand mechanism for reduced muscle function (6). Furthermore, damaged structures and molecules must be removed and replaced and this is generally a time consuming process (i.e., days; (28)). Indeed, high force eccentric exercise may inflict considerably muscle damage and prolonged recovery times (18). Strong correlations have been reported between signs of muscle damage and recovery of muscle function (17; 18; 21). Consequently, when applying very heavy loads, or high-force eccentric exercise, the exercise may induce a forceful, prolonged protein turnover and the training frequency must be rather low (e.g. 1-3 sessions per week).

Experiments with low load strength training (including BFR exercise) indicate that this approach causes low to moderate degree of muscle damage, but still large gains in muscle mass over short training periods (15; 27). This indicates that muscle damage is not an essential component in the hypertrophy signaling (23). The term "muscle damage" is, however, a somewhat difficult concept, but herein defined as damage to myofibrillar structures concomitant with reduced muscle function (18). In addition to the load, the recovery period is dependent on exercise volume (sets x repetitions; (4; 16)). Interestingly, when applying the same training volume per week, it seems advantageously to choose a high training frequency: e.g., 3 sessions per week are better than 1 (14), and 6 are superior to 3 sessions per week (20). Thus, there is certainly a limit to how much exercise the muscles are capable to respond to in a given session, and therefore may a moderate exercise volume per session and a high training frequency be the most effective strategy in order to get frequent rises in the net protein synthetic rate. This is, however, not strait forward, because others have found no effects of different training frequencies when performing the same training volume per week (5).

In summary: The recovery period seems strongly dictated by the degree of muscle damage inflicted during exercise. However, exercising with high – muscle damaging – loads is not necessarily superior to low – "gentle" – loads in inducing muscle growth. From this it may be assumed that changes in the net proteins synthetic rate are not well correlated with the recovery period. Furthermore, it can be hypothesized that the protein synthetic rate can only be augmented to a given maximal speed and increasing the exercise stimuli further by heavier loads (e.g., maximal eccentric actions) and/or larger training volumes will only prolong the recovery period due to muscle damage. It can, however, not be excluded that such heavy load training (e.g., eccentric exercise) induces adaptions beyond muscle growth, e.g., changes in the connective tissue and/or "qualitative" changes in force-transmitting structures that are of advantage in various sport disciplines.

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EXERCISE-INDUCED CHANGES IN MUSCLE DAMAGE, PROTEIN SYNTHESIS RATE AND RECOVERY OF FUNCTION: IS THERE A LINK?

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The balance between muscle protein synthesis (MPS) and muscle protein breakdown (MPB) dictates net muscle protein balance (NPB). Following contractile activity, MPS is transiently elevated to a greater extent than MPB and with nutrients ingestion produces a positive NPB, thereby permitting the accretion of muscle protein. On a chronic basis frequent exercise-induced elevations in MPS, in combination with a nutrient milieau, summate to 'drive' muscle adaptation to exercise training. The types of muscle protein that are synthesized depends on the mode, intensity and cadence of muscle contraction. As an individual adapts to a training protocol the muscle protein synthetic response progresses from the global synthesis of all muscle proteins in the untrained state, to specific proteins needed for structural and metabolic adaptations to the particular exercise stimulus as one becomes 'better' trained [1,2]. In the case of resistance exercise the synthesis of myofibrillar proteins predominates and, over time, translates to myofiber hypertrophy. Recent work demonstrates that resistance exercise-induced rates of MPS and hypertrophy are not dependent on the load lifted but, instead, the maximal recruitment of muscle fibres which can be achieved via lifting light or heavy loads to the point of volitional fatigue [3-5], or under ischemic conditions [6]. In the post-exercise period rates of MPS can remain elevated above rest for up to 48 h [7]. Given that the greatest resistance exercise-induced rise in MPS occurs immediately following the bout [8], the synergistic effect of nutrient provision on exercise-induced MPS rates is likely to be greater during this period. However, recent work from our lab shows that prior resistance exercise contraction performed to fatigue can prolong the sensitivity of the muscle to nutrients at 24 h post-exercise [9].

Isotonic resistance exercise incorporates shortening (concentric) and lengthening (eccentric) contraction of specific muscles. The symptoms of exercise-induced muscle damage (EIMD) include elevations in Z band streaming, blood levels of intramuscular proteins and pro-inflammatory cytokines, delayed onset of muscle soreness - which typically peaks somewhere between 24-72 hours post-exercise and edema. Of interest to athletic populations is the fact that EIMD impairs muscle strength and function [10]. The extent of decrements in strength/functional with EIMD are typically examined by maximal strength (i.e. 1RM, maximal voluntary contraction) or performance tests (i.e. vertical jump, time-trial performance) and subjective ratings of muscle soreness (i.e. visual analogue scaling). Given that the symptoms of EIMD can last from days to weeks after the initial bout, the corresponding decline in function will likely hinder an athletes' ability to perform high-intensity training on subsequent days, which may affect competition preparation and performance. In fact, following damaging exercise it is commonplace for the majority of athletes to alleviate the symptoms associated with EIMD in order to fully recovering any loss in muscular strength and function that may have occurred. On the other hand, traditional thinking is that EIMD is required, to some extent, to facilitate muscle growth [11-13], hence the classic bodybuilding mantra "no pain, no gain". Therefore, an important question is, should athletes seek to attenuate the symptoms of EIMD in order to recover muscle function if this process plays a role in 'driving' MPS and adaptation? The answer, no doubt, has important implications for resistance training programme design.

It has been clearly demonstrated that eccentric contractions elicit greater levels of EIMD than isometric or concentric contractions, due to the mechanical insult elicited by lengthening contractions. Mechanistically, during lengthening contractions the muscle tension generated increases along with the distribution of load among the fibres (particularly fast twitch [14]), resulting in a higher load-to-fibre ratio. Thus, highly damaging eccentric exercise has been suggested as a potent stimulus to induce hypertrophy. Evidence to suggest resistance exercise training protocols that elicit high-levels of EIMD promote superior hypertrophic gains is equivocal. Potential mechanisms to explain the how EIMD mediates growth centre around the inflammatory processes thought to regulate MPS and satellite cell activity (for review see [15]). Indeed, our lab has shown that a single bout of eccentric exercise elicits considerable EIMD and stimulates greater rates of MPS compared with a volume-matched bout of concentric exercise [16]. Others have shown that attenuating the symptoms EIMD and improving functional recovery, with the use of over-the-counter non-steroidal anti-inflammatory drugs (NSAID's) [17-20], may blunt rates of MPS and reduce satellite cell activity [21,22]. Thus, acute investigations suggest that there is a relationship between EIMD and exercise-induced rates of MPS, but how do these acute findings translate to long-term muscle adaptation? Our lab compared the effects of 9 weeks of eccentric and concentric training (2 x per week) and found that both contractile modes produced a comparable hypertrophic response [23], despite greater EIMD with eccentric training [10]. These data are in line with research showing that training-induced hypertrophy can occur without significant EIMD [24,25]. Further to these data, a 12 weeks resistance training study showed hypertrophy was, interestingly, more pronounced in individuals consuming NSAID's on a daily basis throughout training. Thus, from these data it is clear that, although acute rates of MPS may be influenced by the level of EIMD, NPB is not elevated further, which indicates a concomitant change in MPB. Put another way, EIMD does not appear to 'drive' the accretion of myofibrillar proteins, but instead appears to stimulate greater rates of myofibrillar protein turnover required for greater acute-phase tissue remodelling and removal of degraded muscle proteins. This hypothesis is highlighted further in Figure 1. Due to technical challenges, measurement of MPB and subsequent NPB, in response to damaging exercise has proved elusive and, thus, a link between EIMD and MPB has not yet been demonstrated. However, earlier studies have demonstrated that damaging eccentric exercise increases whole-body measures of protein breakdown [26,27]; leading to the conclusion that EIMD is responsible for these changes. Finally, it is important to point out that perhaps some EIMD may be required to initiate processes involved in tissue remodelling and adaptation, but surpassing this 'damage threshold' will not enhance the adaptive response and may, in cases where sever damage is induced, serve only to delay the recovery of muscle strength and function.

If damage *per se* is not a critical determinant of training-mediated hypertrophy, then it may be pertinent for athletes to employ strategies designed to attenuate the deleterious symptoms associated with EIMD in order that they may hasten functional recovery and return to training. As discussed above, the use of NSAID's reduces muscle soreness [20] and expedites strength recovery [28]. However, given that damage-inducing contraction does not appear to be a requisite for muscle growth, the levels of EIMD elicited by conventional lifting paradigms may not be severe enough to warrant regular consumption of NSAID's. In spite of the fact that they do not appear to impede hypertrophy, our perspective is that the use of NSAID's should be limited to scenarios in which EIMD is severe (i.e. performing unaccustomed exercise or returning from a lay-off). To date, there is insufficient mechanistic evidence to back claims that NSAID administration enhances hypertrophic adaptations to resistance exercise. Over the last decade a number of studies have shown ingestion of protein/amino acid supplements following damaging exercise ameliorates EIMD symptoms following strenuous exercise, but with little influence on the recovery of strength and function [29-32]. However, recently Howatson and colleagues showed that the potential of BCAA to restore post-exercise decrements in strength may occur only in well-trained individuals [33]. Mechanistically, damaging exercise increases the uptake of amino acids into the muscle to facilitate MPS for muscle remodelling and BCAA ingestion in close proximity to damaging exercise reduces BCAA oxidation [32].

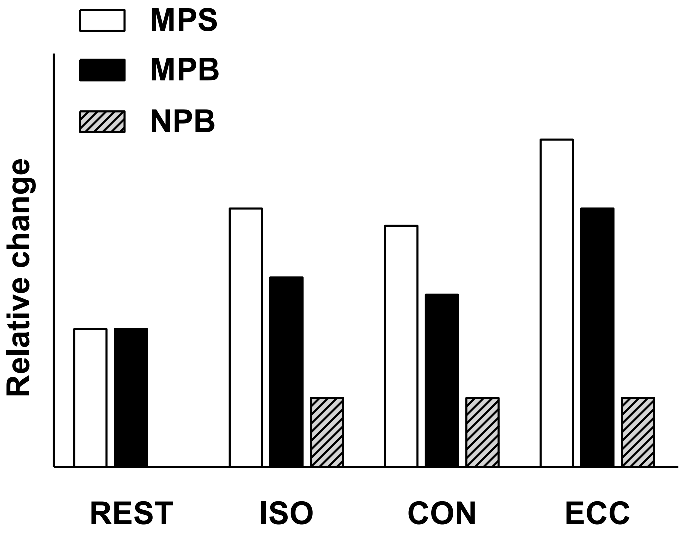

Figure 1. Hypothetical representation of skeletal muscle protein turnover in response to isotonic (ISO), concentric-only (CON) and eccentric-only (ECC) resistance exercise contraction compared with rest (assuming net protein balance). Note that NPB is enhanced following resistance exercise, as the increase in rate of MPS exceeds MPB. There is a greater rise in the rate of MPS following eccentric contraction due, we propose, to the high levels of EIMD elicited; however, NPB following ECC is similar to other contraction modes due to the relative increase in MPB required to remove damaged/degraded proteins.

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CELL SIGNALING AFTER RESISTANCE EXERCISE: MECHANICAL VS. METABOLIC STRESS

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INTRODUCTION

The overall degree of mechanical stress is usually a function of intensity (load) and time under tension (sets x repetitions x time). Resistance exercise with a high intensity (>85% of 1RM), primarily designed to maximize neural adaptation, does not normally lead to large changes in muscle hypertrophy if the total volume or time under tension is low, e.g. low amount of repetitions per set and number of sets (10, 14).

Metabolic stress refers to acute depletion and restoration of ATP by anaerobic energy metabolism (during resistance exercise). This is associated with e.g. changes in different metabolites and also ischemia of some degree. Typical response is also temporarily increased muscle size because of the fluid movement from circulation into active muscles (24). These responses are usually accomplished in exercises that have large time under tension but lower intensity. This type of "hypertrophic" training traditionally consists of a rather large number of repetitions (~8-12) per set with medium loads (60-85% of 1 RM) (32, 33).

A NEW TREND IN BODYBUILDING SCIENCE: RESISTANCE EXERCISE WITH LOW LOADS

Rather low mechanical but high metabolic demands of exercise with very low ~20-50 % 1RM loads, either using bodybuilding type of training (21, 30, 34) by continuous tension technique (blocks part of the blood flow) or ischemic training by using an artificial blood flow restriction (35), has been recently successfully used to increase muscle size. However, this has been studied only in some muscles and mainly in untrained individuals. Low load training either with normal speed or slow-speed may not be an optimal strategy for even muscle hypertrophy in more traditional type of strength training (27).

Studies have also compared different types of rest-pause techniques, with equal or close to equal total volume and intensity, to more continuous sets that induce larger metabolic stress in muscles. Interestingly, gains in maximal strength (11, 26) and muscle size (11) were smaller, at least in some muscle groups, in the rest-pause exercise workouts that induced smaller metabolic stress for muscles. Furthermore, adding a bodybuilder-type fatiguing "pump-set" at the end of the training bout or simply combining high-intensity and lower intensity training may further enhance adaptations (12). Collectively, these studies suggest the importance of metabolic alterations on muscle growth.

A very high volume (e.g. > 140 total repetitions per muscle group per session) and thus also metabolic demand, does not lead to larger muscle size adaptation than exercise with medium volume (36). Reasons for this may be a negative influence from large energy use and stress or the fact that eventually this type of exercise starts to resemble endurance training with less anabolic effects (2). Too much of endurance training (i.e. of heavy running) can decrease muscle size and strength adaptation to resistance training (38).

SIGNALS MEDIATING SKELETAL MUSCLE REMODELING BY RESISTANCE EXERCISE

Mechanistic Target *O*f *R*apamycin complex 1 (*mTORC1)* involving at least six proteins has been said to "regulate almost everything" (20) (see figure below). mTORC1 seems to be the most important protein also in mediating resistance training adaptations (for a comprehensive review see Philp et al. (23) and figure below). Blocking of mTORC1 with rapamycin prevents mechanical loading-induced increase in muscle size (4) and muscle protein synthesis response to resistance exercise (8). Furthermore, tens of studies have shown that mTORC1 is activated after a resistance exercise workout, usually estimated by the hyperphosphorylation of S6K1 at Thr^{389} (e.g. 5, 6, 8, 9, 17, 18, 21, 31, 37).

PROTEIN SYNTHESIS VS. PROTEIN BREAKDOWN, AND EXERCISE *PER SE* VS. NUTRITIONAL INTERVENTIONS

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INTRODUCTION

After a bout of resistance exercise, mixed muscle protein synthesis rate increases (Biolo et al, 1995; Phillips et al, 1997; Phillips et 1999; Pitkanen, et al, 2003). Muscle protein breakdown also increases although to a lesser extent. Thus, the net balance between them (synthesis minus breakdown) improves, but generally does not reach positive values unless nutritional support is provided (Biolo et al, 1997). During the recent years, much research has been performed on the regulatory mechanisms underlying initiation of protein synthesis post-exercise. Less is known about the regulation of muscle protein breakdown *in vivo*.
Muscle proteins are synthesized from the free amino acid pool in the muscle. The size and composition of this pool depend on inward and outward transport of amino acids, their disappearance into and appearance from protein (i.e., protein synthesis and breakdown), and the de novo synthesis and catabolism of the amino acids. Amino acid transport rates are proportional to the existing amino acid concentrations inside and outside the sarcoplasmic membrane.

This presentation will discuss the effects of nutritional stimulation in the post-exercise period on muscle protein breakdown and net protein balance. It is postulated that protein breakdown is linked to protein synthesis, and that this is partly regulated through maintenance of the free intracellular concentration of essential amino acids.

RESULTS & DISCUSSION

In the post-exercise period, protein synthesis increases and is stimulated by amino acid infusion or intake (Biolo et al, 1997; Tipton et al, 1999; Børsheim et al, 2002). Protein breakdown also increases, although to a lesser extent. Whereas infusion/intake of amino acids during rest does not affect protein breakdown, intake of amino acids post-exercise attenuates the post-exercise increase in protein breakdown (Biolo et al, 1995). Local hyperinsulinemia suppresses accelerated muscle protein breakdown after exercise, but not normal resting breakdown (Biolo et al, 1999). Thus, factors regulating muscle protein breakdown in human subjects are complex and interactive. Intake of carbohydrates after resistance exercise, lowers protein breakdown, but the effect on net protein balance is small and delayed (Børsheim et al, 2004).
In studies were extracellular concentrations of amino acid were increased 40 percent above basal levels by amino acid infusions (Bohe et al, 2003) or artificially lowered 40 percent below basal levels by hemodialysis (Kobayashi et al, 2004, Børsheim et al, 2006), the intracellular essential amino acid concentrations remained constant. Protein synthesis changed according to changes in the extracellular levels, whereas protein breakdown remained unaffected. Only when the rate of infusion of amino acids increased sufficiently to exceed the capacity of synthesis to increase proportionately, did the intracellular concentration of amino acids increase (Bohe et al., 2003).
In catabolic states, e.g., after a burn injury, muscle protein breakdown is massively elevated to serve the need for amino acids in wound healing, acute phase protein synthesis etc. In this state, protein synthesis is not decreased, but rather also elevated, although to a lesser extent than the protein breakdown, resulting in a net loss of muscle proteins (Biolo et al, 2002). In these circumstances, there is a paradoxical effect of amino acid infusion, with no effect on muscle protein synthesis, but an attenuating effect on protein breakdown (Porter et al, *In submission*).
There are multiple pathways by which muscle protein breakdown can occur, and these pathways may be independently regulated. It is likely that the proportionate role of these pathways depend on the physiological circumstance, and thus that the *in vivo* regulation of breakdown is complex. *In vivo* there is a link between protein synthesis and breakdown that may be regulated partly through the intracellular essential amino acid pool. The observation that muscle protein synthesis and breakdown are linked as part of a system to maintain a constant free intracellular amino acid pool, is supported by results showing increase in protein breakdown

post-exercise when no amino acids are provided, and an attenuation when amino acids are administered. However, it can also be explained by different regulation of protein breakdown during rest and post-exercise.

CONCLUSION

It is postulated that protein breakdown is linked to protein synthesis, and that this is partly regulated through maintenance of the free intracellular concentration of essential amino acids. Muscle protein breakdown is paradoxically elevated in the anabolic state following resistance exercise, possibly in part because the even greater stimulation of synthesis would otherwise deplete this pool. Thus, factors regulating muscle protein breakdown must be evaluated in the context of the prevailing rate of muscle protein synthesis. Further, the direct effect of factors on breakdown may depend on the physiological state.

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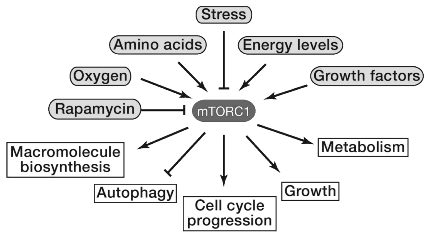

Figure 1. mTORC1 responds to various factors. It promotes cell growth by inducing and inhibiting anabolic and catabolic processes, respectively, and also drives cell-cycle progression. From Laplante et al. (20).

Muscle hypertrophy due to resistance training, seems largely to result from cumulative acute increases in anabolic signaling and consequently muscle (myofibrillar) protein synthesis (37). Possible upstream stimuli that trigger muscle growth due to a resistance exercise bout are e.g. muscle contraction and stretch (mechanical strain and activation of stretch activated channels (SAC) etc.), increased metabolism and metabolites (acidity, Ca2+, AMP, reactive oxygen species (ROS), glycogen etc.), muscle damage or disruptions/deformations and inflammation processes, blood flow changes such as cell swelling and ischemia, amino acid transport and amino acids from the protein degradation, hormones, growth factors and cytokines, nutrition and hydration status etc. The contribution of these obviously depends on the resistance exercise protocol. These factors are, at least to some degree, influenced e.g. by day to day variation, diurnal variation, age, sex, health status, environmental factors, training status etc.

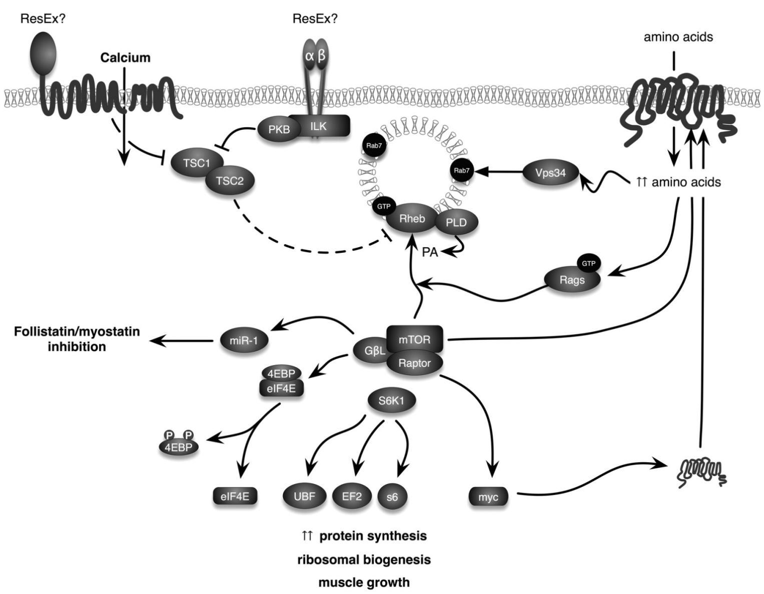

Figure 2. Mechanical activation of mTORC1. Modified from Philp et al. (23).

MECHANICAL VS. METABOLIC STRESS SIGNALING AFTER RESISTANCE EXERCISE

Multiaxial mechanical stretch of myotubes in vitro can activate mitogen-activated protein kinases (MAPK, e.g. Erk 1/2) and mTORC1 signaling in the absence of significant metabolic cost (16). Also maximal eccentric exercise through greater muscle tension and stretching of the muscle even with rather low EMG-activity more effectively activates mTORC1 signaling when compared to submaximal eccentric or maximal concentric exercise (9). We have found that maximal strength type of exercise, with high short-lasting mechanical stimuli but low metabolic demand, does not effectively increase mTORC1 and MAPK signaling in muscles when compared to hypertrophic type of exercise (18). It is unclear how mechanical load/strain activates mTORC1 or MAPK signaling or eventually increases muscle size but potential key players have been reviewed earlier (29 and see also Figure 2).

Also the importance of metabolic stress on muscle growth signaling has been shown in different types of study designs. MAPK family proteins Erk1/2 and p38 can positively regulate muscle size (13, 28), but they may also be involved in muscle endurance adaptations (15, 22, 25, 40). Rahnert JA has shown in rodents that length of contraction is more important on MAPK signaling than varying force levels and that metabolic load of exercise also correlated with MAPK signaling (Rahnert JA, PhD thesis). Wretman et al. examined the importance of metabolic/ionic vs. mechanic perturbations on the activation of MAPK signaling (39). They concluded that in isolated rat skeletal muscle an increase in the phosphorylation of both Erk1/2 and p38 were induced by mechanical forces. In contrast, metabolic/ionic changes (ROS and acidosis) caused increased phosphorylation of Erk1/2 only. A study by Phillips et al. (5) found that increasing time-under tension with equal total volume of very low-load exercise can induce, at least acutely, not just increased myofibrillar protein synthesis and mTOR signaling, but also synthesis of protein fraction of muscle involved in energy metabolism. Indeed, strength endurance type of resistance training can also induce endurance training type of adaptation such as increased strength endurance or aerobic endurance (7).

High enough exercise volume (i.e. at least ~3-5 sets with ~6-12 repetitions) is also important for muscle protein synthesis and mTORC1 signaling (6). However, even as low as 3 repetitions per set (90% of 1RM, 6 sets × 3 reps) may provide untrained muscle an anabolic stimulus in the form of increased muscle myofibrillar protein synthesis (19).

It is possible that earlier signals at 0-1h after resistance exercise have other meaning than later ones at e.g. until 24-48 h. However, mTORC1 signaling has correlated well with the magnitude of hypertrophy in rats as late as 6h after exercise (3) and in humans 30 minutes post-exercise (31). Some of the studies have, however failed to find similar correlations (17, 21). Biopsy sampling at different time points post-exercise makes comparison of published signaling and protein synthesis studies difficult to interpret.

One could argue that a lack of the current literature is that most training and signaling studies conducted so far have used previously untrained subjects and have been short lasting. With a novel training stimulus almost all individuals will adapt and respond with various types of resistance exercise stimulus. In practice, however, the same situation does not hold when the subjects have years of training experience. In summary, rather high muscle time-under tension and metabolic stress, accomplished by large amount of repetitions or slow repetitions, seem to be at least equally as important as intensity/load on muscle hypertrophy (21, 30, 34). However, high loads such as >80 % of 1 RM still remains optimal choice for maximal strength adaptations (1, 10, 21).

CONCLUSION

Typical resistance exercise induces both mechanical and metabolic stress. These stresses and downstream signaling can be difficult to distinguish from each other. This is because, although of lower intensity and mechanical strain, hypertrophic type of resistance exercise with large metabolic cost is usually also associated with large time under tension. Nevertheless, mechanical and metabolic alterations activate signaling pathways such as mTORC1 and MAPK in skeletal muscle, which seem to be important in mediating muscle adaptation to various types of training.

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+Rahnert Anne. Dissertation: Mechanical and metabolic stresses contribute to high force contraction signaling. during his short scientific career.

STRENGTH TRAINING IN TEAM SPORTS

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INTRODUCTION

The team sport environment presents unique challenges for Strength & Conditioning Coaches, but with these challenges comes the opportunity to influence athletic performance through a number of avenues. For example, team sport programs often have potentially competing influences such as the need to develop metabolic capacity, complete large volumes of skill and tactical training in addition to improving strength and power qualities. Whilst the need to develop such a broad range of capacities is somewhat unique to team sport, improving underlying strength and power qualities can potentially impact a variety of important performance components. These include improving sprint speed, jump ability, endurance performance and potentially aid in injury prevention. Various tests of strength and power have also been shown to discriminate between levels of performance, and even well trained team sport athletes can increase strength and power over extended periods. In practical terms, the team sport Strength & Conditioning Coach needs to combine the "art of coaching" with the scientific evidence base to allow the design of an appropriate test battery, determine practically meaningful change, and devise individual periodised training within the scope of a wider program. This process is particularly critical given that the relative importance of strength and power to performance can vary according to the particular team sport. In many cases, the challenges of the team sport environment encourage the development of innovative training techniques.

DISCUSSION

Whilst the importance of strength and power training to performance in a variety of individual sports is well known, there is also a growing body of evidence emphasising the value of this type of training to team sport athletes. For example, recent work using professional rugby league players has demonstrated improvements in sprint speed paralleled improvements in maximal squat strength and a similar relationship appears evident in soccer.[1,2] Furthermore, increased strength has resulted in improved sports specific expressions of strength and power such as vertical jump height in multiple team sports including volleyball, basketball and handball.[3-6]

In addition to the associations between underlying strength qualities and explosive performance in team sport athletes, arguably one of the great benefits of undertaking strength training in this population is the potential to enhance endurance performance via changes in running economy.[7,8] It also appears that specifically targeted strength training may have a critical role to play in injury prevention.[9] Importantly, there seems to be the ability for tests of strength and power qualities to discriminate between performance level. Support for this contention can be found in studies on various team sport athletes including rugby league, Australian football, and volleyball.[10-12]

One of the greatest challenges for increasing strength and power in team sport settings is the need to spend time developing a variety of physical qualities, including technical and tactical training which are superimposed on crowded playing schedules. Despite this challenge, there is strong evidence for maintaining the frequency of strength training in the team sport environment.[13,14] A consistent focus on strength training has been shown to produce long term improvements in expressions of force and explosive ability and even improvements during the competition season.[3,15,16] Such a complex environment can be the driver of innovative training practices. Examples of this in team sports include the use of training methods such as Judo and Wrestling aimed at maximizing the transfer of the strength training stimulus to the field.

Although the degree to which strength and power are important to performance is dependent on the specific team sport, it is critical from a practical perspective to conduct routine profiling of these attributes. This may include the need to assess athletes in a variety of load and velocity conditions.[17] Recent work suggests there may be a place for movements requiring limited skill to form part of these protocols.[18] Central to the process of regular assessment, is the use of valid and reliable protocols and data analysis techniques that allow determination of practically meaningful change to ultimately drive the training prescription process.[19]

CONCLUSION

Team sports often require a complex combination of physical, technical and tactical qualities. Developing underlying strength and power capacity in an attempt to positively influence performance in this environment can be challenging. However, it is clear that not only do improvements in strength and power transfer to performance in force and velocity dependant movements, but that undertaking regular structured strength training can confer multiple benefits on team sport athletes.

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HOW DO THE BEST POWERLIFTERS IN THE WORLD TRAIN?

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Norwegian Powerlifting Federation

INTRODUCTION

Powerlifting is a relative new sport and the first official world championship was held in 1973, after the founding of the International Powerlifting Federation in November, 1972. Nevertheless, national championships was held in the US, GB among other countries, even in the 60`s.

Powerlifting is a sport in which the goal is to lift as much weight as possible for one repetition in three different lifts: the **squat, bench press**, and **deadlift**. The lifter has three attempts in each lift. Importantly, the three powerlifting exercises are widely used as main exercises in strength training routines for many populations, both for recreational strength training and by athletes; using strength training to increase their physical capacity and thereby improve athletic performance.

From the 60's until the 90's, most powerlifters' training routines had strong links to typical bodybuilding type of training, with many lifters crossing over and competing in both sports. However, powerlifting has much more in common with the older sport of Olympic Weightlifting. At this time, the eastern European countries had developed an experienced based understanding for how to train for maximal strength through their focus on Olympic weightlifting. Consequently, when the former USSR countries entered the international powerlifting scene in the 90's, some lifters brought their Olympic weightlifting training methods in to their new sport.

In Norway, a training-revolution in powerlifting started in 1997 with a new coach for the Norwegian powerlifting federation, a German native and former Olympic weightlifter and weightlifting coach. The new coach used his knowledge from his time as a Western German national Olympic weightlifter team member, and adjusted and incorporated weightlifting type of training to match the demands of powerlifting. Through the years these new training routines have been used by almost every single powerlifter in Norway. In parallel with the change in training routines, the new system was implemented in the powerlifting community through education of coaches throughout all layers of the Norwegian powerlifting federation.

RESULTS/DISCUSSION

In the first years with the new training regime in Norway, the work started with experienced senior powerlifters, formerly used to low volume, low frequency, high intensity training. Most Norwegian powerlifters were at this time training 3 days a week, were each exercise were trained once to twice a week. The senior lifters were slowly adapting to the new routines and gradually increasing frequency and volume. Coming in to the 21st century, when younger athletes started training with the new routines, both the training frequency and the total training volume, were dramatically increased, but intensity was reduced. Today, the best lifters typical train squat, bench press and deadlift 5-6 days a week, some even train two times a day.

Practical experience indicated that the new routine with more frequent but smaller training session, a higher volume, and lower intensity, increased performance and reduced the incidence of injuries during training. Importantly, the progress of the training load is carefully monitored and always follows a predetermined plan for a given period. Normally, the progress in training loads is estimated to be slower than what is possible for and inexperienced lifter in order to avoid overuse injuries.

Scientific support for the new training regime was also found in a recent study on national level lifters (Raastad et al. 2012). In this study a group of talented young lifters were divided into two training groups; one group trained the traditional 3 sessions per week routine, while the other group divided each of the three session in two smaller sessions; training 6 small sessions per week. However, the total training volume and the intensity of the training was kept equal in the two groups. The results showed that the lifters in the 6 sessions per week group increased both performance (figure 1) and muscular adaptations (figure 2) more than the traditional 3 sessions per week group during a 15 week intervention period leading up to the national championship.

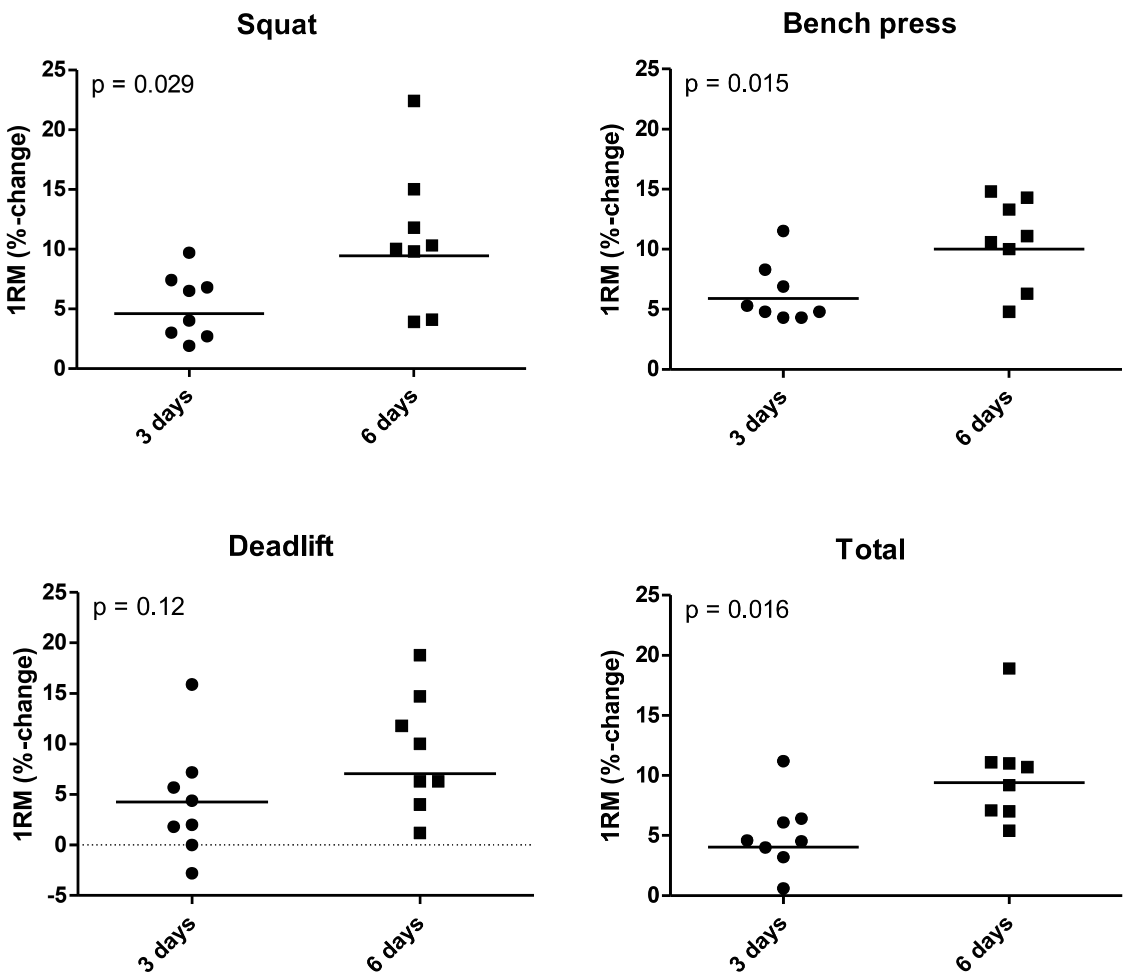

*Figure 1.*Change in 1 RM in squat, bench press, deadlift and total 1 RM performance during the 15 week intervention period in which an equal training volume was divided into either 3 (3 days) og 6 (6 days) training sessions per week.

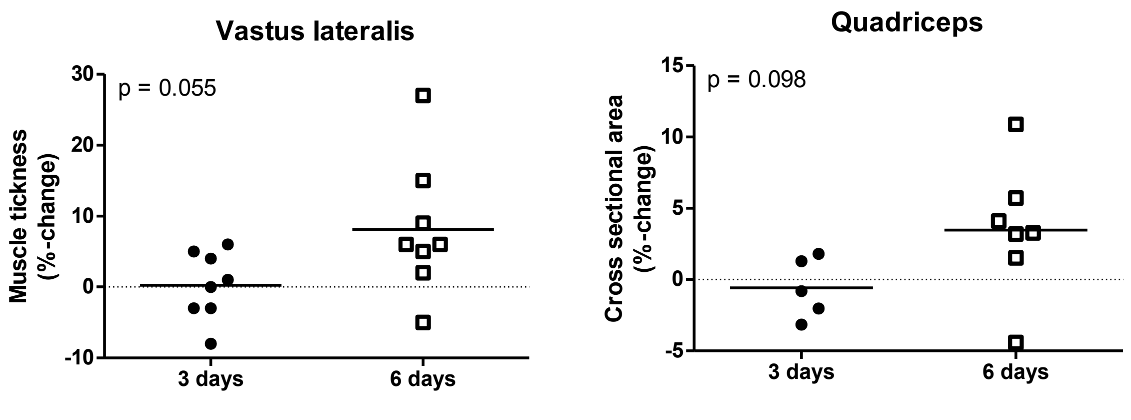

*Figure 2.*Change in muscle thickness of *m. vastus lateralis* (left) and in cross sectional area of *m. quadriceps* (right) during the 15 week intervention period in which an equal training volume was divided into either 3 (3 days) og 6 (6 days) training sessions per week.

Powerlifting equipment (lifting suits and knee wraps) is an important part of the sport, and the lifters ability to master the elastic power of a tight squat suit, or tight knee wraps, are essential for performing at high level (figure 3). Importantly, the support from the elastic properties of the lifting suits alters the force requirements through the different phases of a lift by reducing the muscular load in the deepest positions of all three lift. Consequently, when performing the three exercises without suits, as normally done in practice, the load on the muscles differs from the load met in competitions. Today, Norwegian powerlifters train mostly without the lifting suits, but the use of support from elastic bands has become a more important part of powerlifters training; in order o mimic the elastic properties of tight lifting suits and knee wraps. Different elastic bands have different elastic properties, but the bands used in powerlifting training normally unload the lifted mass by 30-60 kg in the deepest positions.

Figure 3. The three powerlifting exercises performed with lifting suits and knee wraps (squat).

In powerlifting, the athletes normally climb the weight classes in line with their development and gain in muscle mass. The key to a healthy and high quality weight gain, in addition to optimal training routines, is to eat consistently during the day, and to follow a structured meal plan. The meal plan is therefore adapted individually regarding to each body weight category. Powerlifters normally eat 5 - 6 meals consisting of three main meals and some moderate large snacks in-between. The meals and the snacks include high quality protein sources, like lean meat, chicken, fish, eggs and milk and dairy products, combined with low carbohydrates like cereals, dark bread, full corn pasta, full corn rice and potatoes, beans and lentils and sources of essential fats. The timing of meals is highlighted to provide fast recovery after the training sessions. In planned weight gain periods, the use of protein supplements and creatine may be helpful to get the athletes into a positive energy balance and to stimulate muscle hypertrophy. Basically protein-, weight gain-, or other supplements can be useful to gain weight and strength in concentrated periods, but such supplements should not be replacements for nutritious food.

In this presentation focus will be on how and why the training routines have changed over the years. Furthermore, comments will made on why this type of training, at this time, is believed to be close to optimal. Comments will also be made on why some renowned training methods, like high intensity eccentric training, is not incorporated as a part of elite powerlifters training routines. Finally, comments will be made on how new research on strength training methods can be implemented in training for powerlifting, and how this in practice may be incorporated as important parts of powerlifting training routines in the future.

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ARCHITECTURAL CHANGES IN MUSCLES WITH STRENGTH TRAINING – APPLICATIONS FOR PERFORMANCE IN POWER SPORTS

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INTRODUCTION

Muscle architecture, which describes the gross size (i.e. length, cross-sectional area) and arrangement of fascicles (i.e. fascicle angle, fascicle length) within a muscle, is the most important determinant of force production characteristics. Although metabolic factors such as fibre type distribution play a key role, fascicular lengths and angles (i.e. fascicle geometry) have the greatest impact on a muscle's functional performance.[1,2] Given that muscle architecture is highly adaptable, understanding how muscle architecture influences force production and, subsequently, how physical training influences muscle architecture, is vital in order to predict functional outcomes of physical training programmes. In the present paper the impact of muscle fascicle length and angle on force production will be discussed, and theoretical predictions of this impact will also be compared to empirical findings from human studies. The effects of physical training will be reviewed (detraining/unloading will not be covered) and possible mechanisms of geometric adaptation will be detailed. Given that the ability to develop forces at high rates, or at fast movement speeds, is integral to many sporting tasks, the paper will focus largely on the importance of muscle architecture in 'power' sports.

DISCUSSION

Impact of fascicle angle and length on force and power production – theoretical predictions

In many muscles, the fibres, which coalesce into larger functional units called fascicles (which can be observed using medical imaging techniques; see Figure 1), attach at an angle to the tendon or aponeurosis. Such pennation is considered to improve maximal force production because it allows a greater quantity of contractile tissue to attach to a given area of tendon or aponeurosis. As muscle fibres bulge during shortening, the increase in intramuscular pressure forces rotation of the fibres,[3] so muscle shortening is actually accomplished by both a shortening and rotation of fibres. This ensures that the overall muscle shortening exceeds fibre shortening, creating a gearing effect. This can increase force production by optimising fibre force according to both length-tension and force-velocity relationships, as fibres shorten less and at a shorter rate than the whole muscle. Thus, training strategies that increase fascicle angles (at least to a finite point; ~45°) are expected to increase peak muscle force production and, because muscle power is a function of muscle force and shortening velocity, increase muscle power.

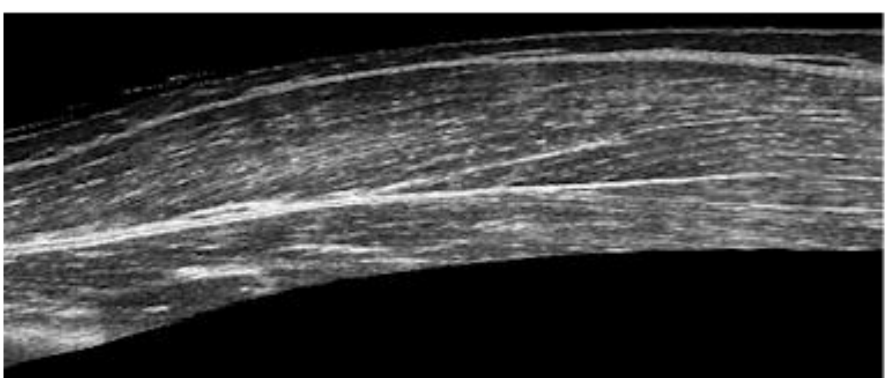

Figure 1. Extended field of view ultrasound image of the longitudinal cross-section of vastus lateralis. Fascicles are seen to attach at angles to the aponeurosis and only run part of the length of the muscle. During active muscle shortening, these fascicles both shorten and rotate, so whole muscle shortening is greater than fascicle shortening.

Muscle fibres either run almost the entire length of their fascicles (in short fascicles) or interdigitate in series with other fibres (in long fascicles). Thus, the fascicle is often considered the most significant functional unit, and the number of sarcomeres in series within long fascicles can be assumed to be greater than in short fascicles. Increasing the number of sarcomeres in series allows for greater maximum fascicle shortening speeds, because shortening speed is directly proportional to the number of in-series sarcomeres (assuming minimal energy is lost from each sarcomere during the contraction process). Also, the force produced by a fascicle is expected to be greater for a given shortening distance and speed in a long compared to a short fascicle because each sarcomere can shorten less and at a slower speed for a given overall fascicle shortening. Thus, sarcomere force is optimised according to the length-tension and force-velocity relations.

Given that muscle power is a function of muscle force and shortening speed, muscle power should theoretically be greater in muscles with longer fascicles.

Impact of fascicle angle and length on force and power production – empirical results

When considering muscle architecture variations between individuals, it has been found that: 1) moderate correlations are often seen between muscle thickness or cross-sectional area and the fascicle angle,[4,5] 2) fascicle angle is often well correlated with peak joint torque production,[6,7] 3) increases in muscle size and strength induced by strength training are often accompanied by increases in fascicle angle,[8-11] and 4) the time course of fascicle angle change tends to mirror that of muscle size (e.g. muscle thickness).[9] Thus the theoretical prediction, that increases in fascicle angle might accompany increases in muscle size and be associated with improvements in force production, is largely compatible with empirical findings in humans. However, some exceptions are seen. For example, no correlation was observed between muscle fascicle angle and powerlifting performance in well-trained powerlifters[12] and the significant correlation between fascicle angle and maximum triceps brachii power ($r = 0.52$) was largely nullified when normalised to muscle volume ($r = 0.39$).[7] Also, strength training leading to increases in muscle size and strength are not always associated with increases in fascicle angle,[9,13-15] and analysis of data from longitudinal studies does not always show a significant correlation between changes in either muscle size or strength and fascicle angle. Thus, other factors might influence the change in fascicle angle with training, possibly including changes in the 3D organisation of muscle, changes in resting intramuscular pressure or changes in intra- fascicular connective tissue properties. Certainly, factors other than fascicle angle may have a very strong contribution to changes in strength and power.

With respect to fascicle length, it has been found that: 1) a significant portion of the inter-individual variability in peak fascicle shortening velocity can be accounted for by variations in fascicle length,[16] 2) longer fascicles are typically found in important propulsive muscles of faster sprint running athletes,[17-19] and 3) the removal of heavy strength training but addition of sprint/jump training in athletes is associated with increases in fascicle length.[20] Thus, in agreement with theoretical predictions, longer fascicle lengths appear to be associated with improvements in high-speed force production (i.e. muscle power). However, exceptions are also seen. For example, correlations between fascicle length in propulsive muscles and sprint running performance are not always seen,[21-22] the performance of well-trained powerlifters (who lift very heavy loads at relatively slow velocities) was greater in athletes with longer fascicles in the triceps brachii, and increases in fascicle length induced by isometric strength training were not associated with changes in dynamic (either slow or fast speed) force production.[23] Importantly, we know very little about how fascicle length adapts to high-speed training, although jump-squat training has been shown to increase fascicle length,[24] and few data exist correlating the training-induced changes in fascicle length with changes in high-speed force production. Thus, while it is currently assumed that increases in fascicle length should positively impact on muscle shortening speed, and hence muscle power output, more data are required to fully understand the impact of fascicle length and the minimum change required to have a positive effect on muscle force, and power, production.

Effects of physical training on fascicle geometry

Increases in muscle fascicle angle appear to be most easily elicited through heavy weights training, where considerable muscular hypertrophy is stimulated. There are insufficient data available to fully determine how smaller variations in load and velocity characteristics affect fascicle angle adaptation, and it is dangerous to pool data from different research groups since methods of measuring fascicle angle changes vary considerably. In order to more fully understand how load and velocity characteristics impact on fascicle angle, a concerted, and precise, effort is required to detail the changes in response to training across the load- velocity spectrum.

Although it is commonly considered that increases in fascicle length might be desirable in order to improve high-speed force production, few studies have examined the effects of higher-speed training on fascicle length adaptations[20,24] and the observed changes were similar to those reported after training at slower speeds under heavier loads (~5-10% in most studies).[9,11-25] In fact, the most commonly reported training strategy thought to increase fascicle length is eccentric training. This stems from research on rats conducted by Lynn & Morgan[26,27] and Butterfield et al.,[28] who reported increases in sarcomere number in the vastus intermedius muscle of rats that ran downhill (and an eccentric load was assumed to be imposed) but decreases in number in rats that ran uphill (concentric load was assumed). Also, increases in fascicle length have been reported in eccentrically-trained muscles in humans.[14] However, although Butterfield et al.[28] used sonomicrometry to measure length changes in the vastus lateralis muscle and found that the muscle was largely lengthening in downhill running and shortening in uphill running in rats, it cannot be assumed that the vastus intermedius was working in sync since it is well known that synergistic muscles can adopt widely varying contraction patterns to their partners during simple joint flexion and extension tasks.[29-30] In fact ,Butterfield et al.[28] found a decrease in vastus lateralis sarcomere number was seen in both the 'uphill' (-4%) and 'downhill' (-5.3%) rats. These results, combined with other data showing no change in sarcomere number after eccentric training in animals,[31] a lack of change in fascicle length in humans,[32] and a comparable fascicle lengthening between groups training with concentric vs. eccentric contractions,[9] suggest that contraction mode is not a major factor influencing fascicle length.

Other data, obtained in rat studies, are suggestive that training either at long muscle lengths[33] or through large excursions[34] might stimulate sarcomere number adaptations. However, data recently obtained in humans indicates that the muscle length at which loading is imposed is not a major factor because fascicle lengthening was observed in groups who trained isometrically at long vs. short quadriceps muscle lengths.[23] Thus, the training stimulus that most optimally elicits fascicle length change is currently not known, although it seems clear that many forms of physical training might lead to moderate increases in fascicle length. Whether such changes are sufficient to alter force and power production characteristics remains to be determined.

Other considerations – Fascicle length and rate of force development

The rate of muscular force development (RFD) is often considered an important factor influencing sports performance. Although increases in fascicle length might be expected to increase RFD because of a fast muscle shortening velocity, muscles also possess significant series elasticity. Series elastic elements must also be stretched during muscular contraction before force is transmitted to the bones to generate movement. Edman & Josephson[35] found that approximately 40% of the time to achieve 50% MVC in frog muscle fibres (devoid of tendon) can be attributed to the need to stretch intramuscular series elastic elements. In fact, results from Blazevich et al.[36] suggest that individuals who show the greatest shift in their knee joint torque- angle curves towards longer muscle lengths (assumed to partly result from fascicle lengthening) after 5 weeks of strength training showed the least improvement in RFD. Thus, longer muscles, or muscles with long fibres, might not be ideal for fast RFD because of their greater series compliance.

Other considerations – Muscle blood flow and muscle fatigue

Rates of peripheral muscle fatigue during high-intensity work bouts appear to be substantially influenced by muscle blood flow capacity. Increases in muscle force result in proportional increases in intramuscular pressure, which can occlude blood flow,[37] and this increase in intramuscular pressure is greater in muscles with larger fascicle angles or greater fascicle curvature. [37] For example, occlusion in the biceps brachii is reached at ~50% MVC whereas it is reached in triceps brachii at ~25% MVC.[38] Thus, blood flow during high-intensity work bouts may be more compromised in muscles with significant fascicle angulation or curvature, and training that induces such changes might negatively impact on fatigue during such work bouts. Nonetheless, the relationship between muscle architecture variables (or changes in them with training) and muscle fatigue during high-speed tasks such as jumping, running or pushing has not been explicitly tested, so it is not clear whether muscle architecture is an important determinant of muscle fatigue in these pursuits.

CONCLUSION

Muscle architecture is the most important determinant of muscle function, and strength training appears to have a considerable effect on muscle size, fascicle angle and length. Increases in fascicle angle are probably ideal for improvements in peak muscle force whereas increases in fascicle length might improve muscle shortening speeds. Whilst much empirical evidence exists to substantiate these claims, other reports to do not match these hypotheses. Despite the increase in measurement of fascicle angle and length in both cross- sectional and longitudinal studies there is still a lack of sufficient data to form a complete picture, and efforts to pool data across research groups is hampered by the variability of methodologies used to obtain the data.

The type of training that best elicits fascicle angle and, particularly, length change is not currently known. Importantly, it is still debatable whether changes in fascicle length that are commonly observed are sufficient to promote increases in fast force production (i.e. muscle power). As a cautionary note, increases in fascicle length might not be appropriate for athletes who require fast rates of force development; thus, training programs may need to differ between athletes who require fast muscle shortening speeds versus those who require fast rates of force development. Also, increases in fascicle angle and curvature might also reduce muscle blood flow and thus increase the rate of muscle fatigue. Hence, a multitude of considerations are necessary in order to determine a muscle’s optimum architecture, and what training to develop to induce it.

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THE ENDOCRINE SYSTEM AND STRENGTH TRAINING ADAPTATIONS IN MEN AND WOMEN

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In endocrine hormone functions, a specific stimulus causes the release of a chemical messenger that travels through the blood in order to reach specific tissue cells and signal for enhanced protein synthesis, reduced degradation, and ultimately, enhanced muscle mass and/or improved force production. Acute and long-term adaptations to strength training begin with motor unit recruitment that results in a milieu of hormone interactions. Much work has been done to understand the complex role of endocrine hormones in the acute and chronic processes that underlie adaptations to exercise, which are a function of the acute program variables of training and upper regulatory elements such as age, gender, training history, and nutrition. Hormonal actions are diverse, and affect nearly all physiological functions before, during, and after training. The hormones of greatest interest are those most closely associated with the primary goals of strength training, and these hormones include testosterone, growth hormone (GH) and its various isoforms, insulin-like growth factors (IGF-1), insulin, neurohormones, and glucocorticoids. Since these hormones influence tissue adaptations, an understanding the hormonal processes that take place in the trainee's body is fundamental to successful recovery, adaptation, program design, training progression, and physical performance.

The first phenomenon related to the role of the endocrine system is related to the recruitment of motor units needed which dictate the systematic demand for support. In addition, receptor activations in tissue are related to electrochemical interaction and gating mechanisms. Key to any hormonal interactions for signaling involve the up regulation of a receptor. From the onset, an understanding of motor unit recruitment is necessary to understand the specificity of resistance training and the roles of different physiological systems. Thus, motor unit recruitment is of fundamental importance in the prescription of resistance exercise. Activated motor units stay facilitated for a period of time following use, which is very important for subsequent muscle contractions. That is, maximal or near-maximal contractions elicit a "post-activation potentiation" for subsequent muscle contractions occurring within several seconds to a few minutes following the high-intensity contraction. Importantly, failure of and exercise movement is not representative of use for the entire motor unit pool in a muscle. The systemic demand for endocrine support begins with the activation of the motor units needed to produce the force that will successfully lift a weight. Signal frequency (Hz) is a vital component of motor unit activation because it allows for a recruitment-specific signal that eliminates confounding or inefficient neurological flows which would result in non-specific signals related to the actual demands of recruitment. Accordingly, neurological relays impact the hormonal signaling of many endocrine, paracrine, and autocrine glands in a manner specific to the acute program variables of training. While complex, the relationship between the acute stress of the neuromuscular demands of exercise and the multivariate configuration of workout variables is what determines the physiological support systems needed to maintain physiological homeostasis and adaptation.

The hormonal mechanisms controlled by the endocrine system can be activated in response to an acute resistance exercise stress or be altered after a chronic period of resistance training. The mechanisms that mediate acute homeostatic changes typically respond to acute resistance exercise stress with sharp changes in hormonal concentrations in order to regulate a physiological function such as protein metabolism or immune cell activation. A more subtle increase or decrease usually occurs in chronic resting hormonal concentrations in response to resistance training. Since numerous physiological factors affect circulating concentrations of hormones and the acute and chronic responses to them, interpretation of sampled values must be done with care. These factors often include fluid volume shifts, synthesis and storage of glandular hormones, tissue clearance rates, degradation, venous blood pooling, binding protein interactions, receptor interactions, and the timing of sample collection. Taken together, investigations of exercise endocrinology must be carefully planned and interpreted.

Muscle is not the only target of hormonal mediation during resistance exercise. The roles hormones play can be highly diversified, and depend on the physiological status of an individual, each of whom will be expected to require differing levels of cellular adaptation across a range physiological systems. Besides the anabolic function of hormones, many hormones help to meet the metabolic demands of acute strenuous exercise. Regulation of blood glucose concentrations, glycogen storage, and mineral metabolism are all mediated by hormone actions. The complexity of the neuroendocrine system is only emerging, as a myriad of interactions occur among hormones and hormonal factors. This has caused confusion in the interpretation of the role of hormones in training. As an example, the adrenergic changes that arouse the body before higher intensity exercise are a vital signaling mechanism for a broad host of physiological systems, which include everything from increased interactions in the central nervous system to up-regulated beta-2 receptor expression in muscle. With regular training, adaptive changes in adrenal medullary function lead to changes in the production of catecholamines during acute exercise as well as enkephalins involved with immune modulations necessary for repair and recovery. Strength training therefore alters endocrine function across a wide array of systems and structures, and these functions change as hormonal glands themselves respond to the long-term stimuli provided by acute program variables. Lastly, acute and chronic endocrine functions are highly sensitive to modifiable and non-modifiable upper regulatory elements such as training status, nutritional status, stress, sleep, gender, and age.

Testosterone has been one of the primary hormones used to evaluate the anabolic status of the body. Following Leydig secretion in men or adrenal precursor conversion in women, testosterone is bound and transported to target tissues by a where it associates with a membrane-bound proteins or cytosolic receptors, activated, and migrates to cell nuclei interaction with nuclear receptors results in protein synthesis. Increases in peripheral blood concentrations of testosterone have been observed with many types of high-intensity endurance exercise protocols, although the role of bound versus free testosterone requires further clarification. Variations in testosterone's cellular actions may be due to changes in the cell membrane as a result of resistance exercise. In addition, the magnitude of muscle fiber recruitment (e.g., size principle) and possible differences in receptor interactions under various exercise conditions may also play a vital role. Androgen receptors, the primary target of testosterone, are heavily expressed in skeletal muscle and motor neurons, vary by muscle, and show plasticity to training. It is important to note that testosterone may also act indirectly through the promotion of growth hormone release, and the facilitation of neuroendocrine function and performance. These indirect actions highlight the interdependent nature of the endocrine system in influencing the expression of strength.

Growth hormone(s) (GH) are secreted by the pituitary gland in a number of bound, spliced, and aggregate isoforms. The effects of GH have primarily been investigated through the 22 kD recombinant form, which is thought to elicit direct and indirect influence on skeletal muscle anabolism. Various external factors, such as age, time of day, gender, sleep, nutrition, alcohol consumption, and exercise, alter growth hormone release patterns. Since exogenous GH administration in children and adults who are GH-deficient results in increased muscle mass and decreased body fat, GH is believed to play a significant anabolic role in skeletal muscle growth. The binding interaction with human skeletal muscle remains speculative, but GH binds to skeletal muscle in pigs. At the molecular level, the biological roles of the GH "super family" are speculative, but implicated in the control of fat metabolism, protein synthesis, and protein breakdown. How GH interacts with receptors, physiological mechanisms, and its integrated endocrine effects within the context of its many variants is not as well understood as previously thought.

Nevertheless, the distribution of 22 kD and non-22kD isoforms varies in human blood and is thought to be due to differential metabolic clearance, circulating binding proteins, and the formation of GH fragments in peripheral tissues. Because of the complex nature of the family of human GH molecules and its numerous physiological actions, it is possible that some of the effects of the hormone on nutritional metabolism, longitudinal bone growth, and skeletal muscle protein turnover may be controlled by different GH isoforms. Finally, some of the effects of GH are thought to be mediated by stimulating the release of insulin-like growth factors (IGF's) through autocrine, paracrine, and potentially endocrine mechanisms.

Studies have shown increases in circulating GH during and/or after heavy resistance exercise in men, women, and in the elderly depending upon exercise selection, intensity, volume, rest periods, nutritional intake, training experience, and muscle action. Not all resistance training programs will produce a significant elevation in serum 22 kD GH concentrations or in certain variants, thus a threshold volume and intensity may be needed. High correlations have been reported between blood lactate and serum GH concentrations and it has been proposed that H+ accumulation produced by lactic acidosis may be the primary factor influencing 22 kD GH release due to the disruption somatotroph synthesis mechanisms of high molecular weight variants. This finding is supported by an attenuated 22 kD GH response following induced alkalosis during high-intensity cycling. Hypoxia, breath holding, acid-base shifts, and protein catabolism have been reported to influence 22 kD GH release. Thus, the metabolic demands of resistance exercise play a significant role in 22 kD GH concentrations.

Acute resistance exercise has been shown to significantly increase lower molecular weight GH isoforms in women and men, although varying results have been produced with the use of different assaying technologies. Long term increases in GH have also been demonstrated and suggest that higher molecular weight GH may be synthesized adaptively. Collectively, these data show that our understanding of the dynamics of pituitary function in response to exercise is starting to become more complex. GH isoforms, aggregates, and binding proteins could be important hormonal mediators of muscular adaptation, but the nature of their response to different types of resistance training is unclear. Furthermore, interactions between GH and the IGF's and it seems probable that many of the effects of certain molecular forms of GH are direct in their interface with cells while some like the 22 kD GH are mediated in part by the actions of IGF's.

Many of the effects of 22 kD GH are mediated through small polypeptides called insulin-like growth factors (IGFs). The IGFs represent a super family of polypeptides. In cell culture studies, IGF's have been shown to stimulate myoblast proliferation and differentiation, suppress proteolysis, increase glucose and amino acid uptake, and increase protein synthesis in various skeletal muscle cell lines. Several studies have also demonstrated the efficacy of the IGF's to increase protein synthesis in human skeletal muscles and these mitogenic (proliferation), myogenic (differentiation), and anabolic actions help to qualify the profound growth potentiating effects of the IGF's on skeletal muscle.

Factors such as nutritional status and insulin levels appear to play important signaling roles in IGF release. Nearly all IGF's in the circulation, and some tissue-based IGF's, are bound to IGF-binding proteins (IGFB). These IGFBP's regulate IGF availability by prolonging their half lives in circulation (~12-15 hours), controlling their transport out of circulation, and localizing IGF's to tissues. Insulin-like growth factor binding protein-4 (IGFBP-4) has a very high affinity for IGF-I, and has been shown to inhibit IGF-I's myogenic (i.e., differentiation) effects on skeletal muscle. Not surprisingly, it appears that resistance exercise results in decreased human skeletal muscle IGFBP-4 mRNA, while muscle IGF-I mRNA is increased. Such results indicate that free IGF-I concentrations are increased in skeletal muscle following mechanical loading, and probably related to an increased need for processes related to tissue growth and repair. Long-term resistance training results in decreased circulating IGFBP-3 concentrations and increased circulating IGF-I concentrations, these studies suggest potential important roles for both acute, local and chronic, systemic growth factor mediated actions on skeletal muscle for strength and power adaptations.

There are a number of ways for hormones to mediate adaptations to resistance training. While organs such as muscle and connective tissue are the ultimate target cells of most endocrine-related adaptations to strength training programs, many adaptations occur in paracrine (cell to nearby cell), and autocrine (cell to self) systems. How paracrine and autocrine changes are affected by heavy resistance training remains unknown due to methodological difficulties in determining the small changes in cells or in various intercellular spaces. Furthermore, research has been limited to immunoreactive hormones that can be detected. Finally, our understanding of how receptors on target tissues translate the endocrine message is only beginning to develop. Each receptor can be differentially regulated in various fiber types in response to different exercise regimes. These responses at the target level of the cell (e.g., muscle, immune cell, neuronal cells etc.) determine whether a hormonal message is realized. Thus, if the receptors are down-regulated they will interact less with the hormone. If they are up-regulated, they will interact to greater degree with the hormone. The quantity of hormone may therefore be of less importance as the number of receptors that interact with it in target cells and their physiological status to send signaling to the targeted cell involved with the homeostatic or adaptive change needed.

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ORAL PRESENTATION 1

Thursday Oct. 25th,
11:30 – 13:30
(Auditorium A)

11:30 – 11:45
Juha Ahtainen
Comparison of the effects of higher and lower resistance exercise volume on signaling pathways regulating protein synthesis and glucose uptake in skeletal muscle

11:45 – 12:00
Kristian Vissing
Stars signaling: effects of muscle contraction mode and dietary supplementation type

12:00 – 12:15
Renae Stefanetti
Acute atrogene response to single-bout concentric versus eccentric resistance exercise ± whey protein supplementation

12:15 – 12:30
Jean Farup
Whey protein augments both muscle and tendon hypertrophy irrespective of contration mode following resistance exercise training

12:30 – 12:45
Håvard Hamarsland
The effect of a vitamin C+E supplement and a combined omega-3 and protein supplement on recovery from a bout of resistance exercise

12:45 – 13:00
Milan Sedliak
Adaptation to early morning vs. Afternoon resistance training: skeletal muscle hypertrophy and cell signalling

13:00 – 13:15
Stian Ellfsen
Comparing the effects of 12 weeks of blood flow-restricted low-load strength training and 12 weeks of high-load strength training on strength performance and muscle characteristics in untrained women

13:15 – 13:30
Antti A Mero
Effects of whey protein on serum amino acids and hormones, performance, and recovery during a 12-day intensive training period in power athletes

COMPARISON OF THE EFFECTS OF HIGHER AND LOWER RESISTANCE EXERCISE VOLUME ON SIGNALING PATHWAYS REGULATING PROTEIN SYNTHESIS AND GLUCOSE UPTAKE IN SKELETAL MUSCLE

Juha P. Ahtiainen[1], Simon Walker[1], Mika Silvennoinen[1], Heikki Kyröläinen[1], Bradley Nindl[2], Keijo Häkkinen[1], Kai Nyman[3], Juha J. Hulmi[1]

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INTRODUCTION

Resistance exercise (RE) volume (i.e. number of sets per exercise session), until a certain point, has been shown to be positively associated with training-induced gains in muscle strength [3,4] and size [2]. Moreover, higher volumes of RE appear to produce greater benefits in glucose regulation [5] that may counteract insulin resistance. In skeletal muscles, increases in phosphorylation of signaling molecules regulating protein synthesis, such as p70S6K1 and the S6 ribosomal protein, seem to depend on the RE volume [8]. The purpose of the present study was to examine the effect of higher versus lower RE volume on the activation of skeletal muscle signaling proteins regulating protein synthesis and glucose uptake (figure 1).

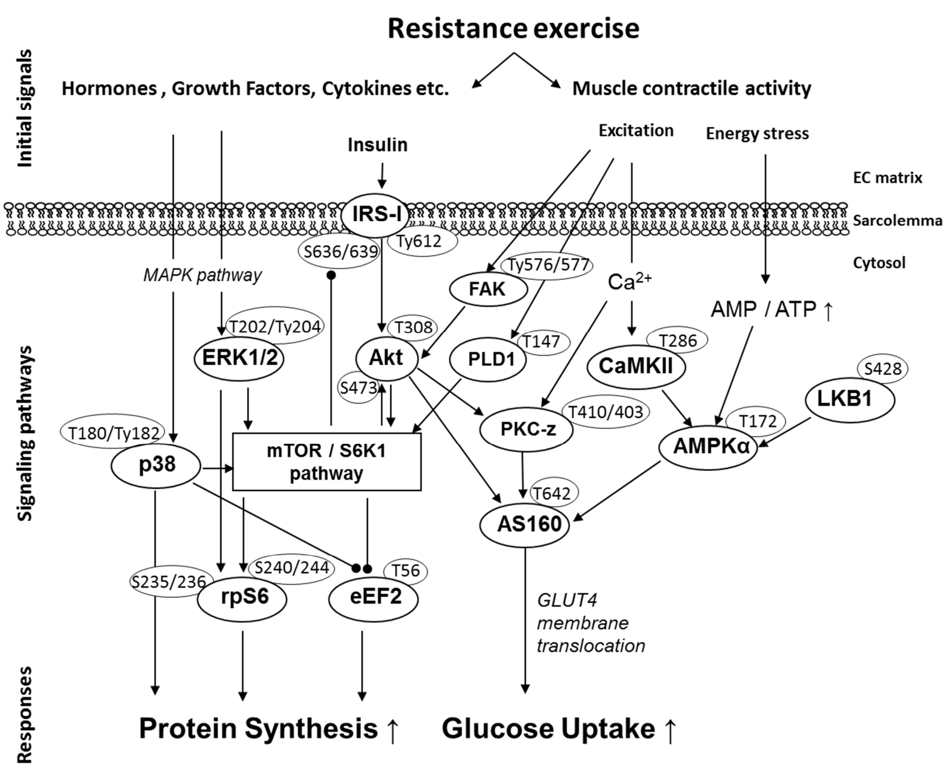

Figure 1. Signaling proteins examined in the present study that regulate protein synthesis and glucose uptake.

METHODS

Healthy male volunteers with no previous experience in regular resistance training were divided into two separate experimental groups; 5 x 10RM (n=8, 28.4 ± 3.7 yrs, 180.3 ± 3.9 cm, 78.7 ± 10.2 kg, 15.4 ± 3.3 fat% , 1RM leg press 184.7 ± 27.9 kg) and 10 x 10RM (n=11, 25.7 ± 3.9 yrs, 181.0 ± 7.7 cm, 78.4 ± 10.9 kg, 12.6 ± 4.3

fat% , 1RM leg press 206.7 ± 25.4 kg) REs in leg press with two-minute recovery periods between the sets. Muscle biopsies were obtained from m.vastus lateralis before and 30 min after the exercises. RE-induced changes in phosphorylation of IRS-I $^{Ser636/639}$, Akt ^{Ser473}, Erk1/2 $^{Thr202/Tyr204}$, p38 MAPK $^{Thr180/Tyr182}$, CaMKII ^{Thr286}, LKB1 ^{Ser428}, AMPK ^{Thr172}, AS160 ^{Thr642}, rpS6 $^{Ser235/236 \text{ and } Ser240/244}$, and eEF2 ^{Thr56} were determined from muscle samples by Western blot. The phosphorylation of IRS-I ^{Tyr612}, Akt ^{Thr308}, PKCzeta/lambda $^{Thr410/403}$, FAK $^{Tyr576/577}$, and PLD1 ^{Thr147} were below the detection limit.

RESULTS

Table 1. RE-induced changes (fold-changes from the corresponding pre-exercise value) in the present signaling proteins. * = statistically significant difference from pre-exercise. # = statistically significant difference compared to 5 x 10RM.

	5 x 10RM	10 x 10RM
IRS-I $^{S636/639}$	4.9 ± 8.0 *	10.9 ± 20.3 **
Akt ^{S473}	0.7 ± 0.2	1.7 ± 1.1 #
LKB1 ^{S428}	2.2 ± 0.8	3.1 ± 1.5 **
CAMKII ^{Th286}	1.5 ± 0.9	1.4 ± 0.6
AMPKα ^{Th172}	0.9 ± 0.5	4.0 ± 2.1 * ##
AS160 ^{Th642}	1.0 ± 0.4	9.8 ± 9.4 * #

	5 x 10RM	10 x 10RM
Erk1/2 $^{Th202/Ty204}$	7.4 ± 4.7 *	17.6 ± 39.9
p38 $^{Th180/Ty182}$	5.0 ± 4.6 **	14.3 ± 24.1 *
rpS6 $^{S240/244}$	10.9 ± 6.2 *	54.2 ± 72.8 **
rpS6 $^{S235/236}$	38.0 ± 45.2 **	86.6 ± 72.6 **
eEF2 ^{Th56}	1.0 ± 0.5	0.8 ± 0.3 *

DISCUSSION

The present results suggest that responses in signaling proteins increasing both protein synthesis and glucose uptake appears to be greater in magnitude in the present higher compared to lower volume RE. Moreover, the data suggest that excitation induced Ca^{2+} and integrin signaling pathways (i.e. PKC-z $^{Thr410/403}$, FAK $^{Tyr576/577}$, and PLD1 ^{Thr147}) are not activated at 30 min after RE. Insulin signaling pathway (i.e. IRS-I ^{Tyr612}, Akt ^{Thr308}) appears to be depressed possibly due to S6K1 activation induced IRS-I $^{Ser636/639}$ phosphorylation that inhibits IRS-I and, thus, insulin signaling [1]. In contrast, higher activation of the MAPK pathways (i.e. Erk1/2 and p38) may have important role in activation of mTOR signaling as well as the changes in rpS6 and eEF2 phosphorylation that have been shown to increase protein synthesis [6,7]. AS160, that induces glucose uptake, appears to be phosphorylated especially due to higher volume RE by AMPKα through activation of LKB1.

CONCLUSION

These findings suggest that the present higher volume RE (10 x 10 RM) may be more advantageous than the lower volume RE (5 x 10RM) for activation of signaling pathways regulating protein synthesis and glucose uptake. Thereby, higher volume RE may potentially promote greater protein accretion as well as enable greater improvements in glucose metabolism compared to lower volume RE in trained skeletal muscles due to long-term resistance training.

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STARS SIGNALING:
EFFECTS OF MUSCLE CONTRACTION MODE AND DIETARY SUPPLEMENTATION TYPE

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INTRODUCTION

Mammalian target of rapamysin (mTOR)-related signaling for muscle protein synthesis is recognized as important and is considered to be sensitive to mechanotransduction during resistance exercise and branched chain amino acids inherent of protein supplements [1]. Repeated stimulation of the mTOR signaling pathway through resistance training and/or protein supplementation is therefore also considered important for promoting muscle hypertrophy. However, other signaling pathways may contribute to muscle hypertrophy. In this respect, overexpression of Striated muscle activator of Rho (STARS) signaling in mouse heart tissue has been linked to increased sensitivity to overload resulting in cardiac hypertrophy [2]. Furthermore, STARS is tied to nuclear translocation of the serum response factor (SRF) and transcriptional co-activator myocardin-related transcription factor-A (MRTF-A), resulting in an increase in SRF-mediated gene transcription during muscle development and remodeling [3]. In one human study by Lamon and co-workers (2009), basal levels of STARS pathway components has been observed to increase in response to conventional resistance training and to decrease with detraining [4]. However, the acute STARS signaling response to resistance exercise has not been characterized and its sensitivity to contraction mode and/or dietary supplementation is unknown. This study therefore investigated the effect of isolated eccentric versus concentric resistance exercise, combined with either whey protein or an isoenergetic placebo supplementation, on STARS signaling.

METHODS

In an unpaired, randomized, double-blinded trial, 2 x 12 healthy untrained male subjects were randomly divided into two independent groups. Both groups performed concentric exercise with one leg and eccentric exercise with the other leg. One group was given a whey protein hydrolysate supplement (WPH), while the other group received placebo (P). Habituation was accomplished by performing 3-4 training sessions over a 10 day period. A single-bout exercise trial was then completed 6-7 days following habituation. During the single-bout trial, eccentric and concentric exercise was conducted in a randomised order using an isokinetic dynamometer. The protocol consisted of 6 sets of 10 repetitions of maximal contraction at 30° x sec^{-1} angular velocity, with 3 minutes recovery between sets. WPH and P supplements were given immediately after completion of each exercise session during the habituation phase as single bolus supplements of 0.30 gr whey protein + 0.30 gr CHO pr. kg LBM or 0.60 gr CHO pr. kg LBM placebo, respectively. Biopsies were harvested prior to and after exercise habituation (3 days after last training session and with 3-4 days prior to the single-bout exercise trial), and at 1, 3 and 5 hours after the single-bout exercise from both legs. Changes in protein expression/phosphorylation was performed for STARS, MRTF-A and pSRF/totalSRF and normalized to GAPDH. Effects of time, treatment and time x treatment were assessed by a 2-way repeated measures ANOVA (accounting for repeated nested measures on each subjects) followed by linear regression analysis to examine differences between individual conditions with $p<0.05$ considered significant.

RESULTS

A contraction x supplement x time effect was observed for STARS protein expression, with an overall increase after exercise habituation, as well as 1 hour after the single-bout exercise bout when compared to pre-habituation basal levels. Concentric contraction mode in the whey group exhibited augmented STARS protein expression 1 hour after the single-bout exercise when compared to post-habituation basal levels and when compared to eccentric contraction and/or the placebo supplementation (Figure 1 A and B). A time effect was observed for MRFT-A protein expression, with an overall increase after exercise habituation as well as 1 and 3 hours after the single-bout exercise when compared to pre-habituation basal; this effect was independent of contraction mode and supplement (Figure 1 C and D). A time effect was observed for pSRF/total SRF at 5 hours after the single-bout exercise bout when compared to both pre- and post-habituation basal levels; this effect was independent of contraction mode and supplement (Figure 1 E and F).

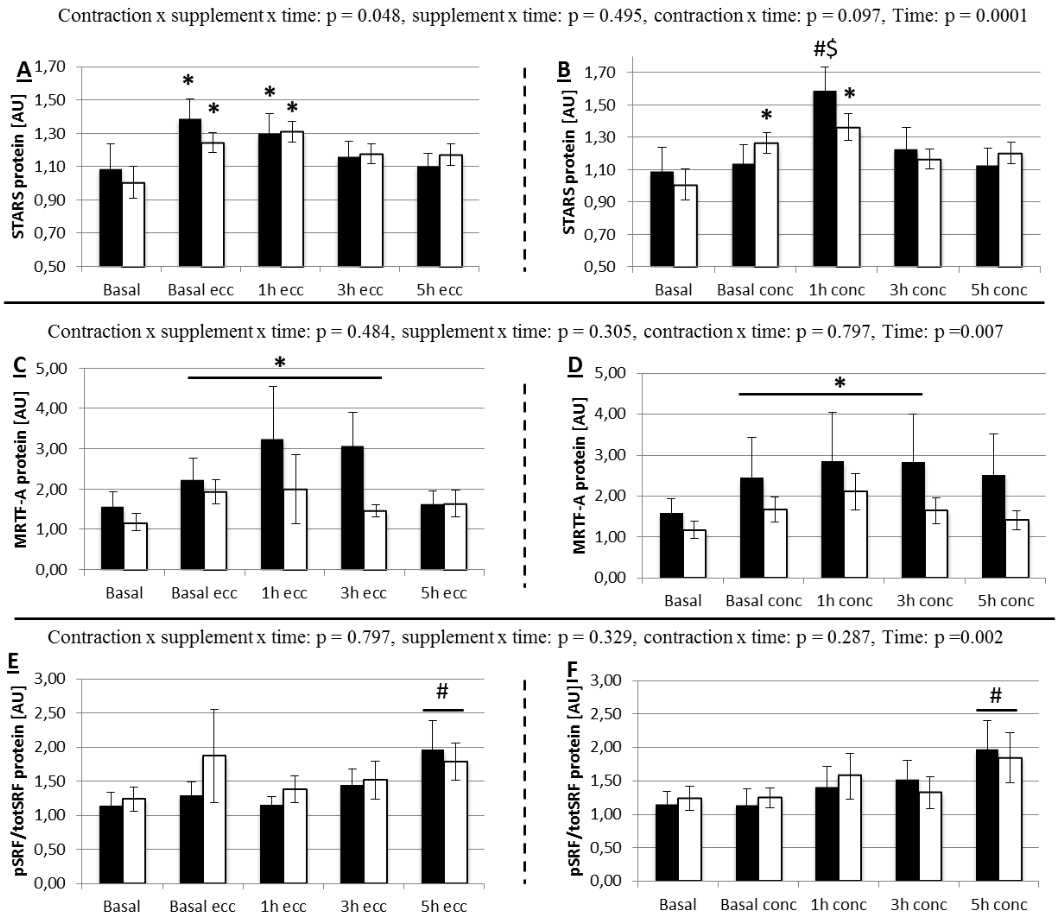

Figure 1. STARS signaling pathway protein expression/phosphorylation. Changes in STARS (**A+B**) and MRTF-A (**C+D**) protein expression and SRF (**E+F**) protein phosphorylation compared to pre-habituation basal is shown as mean arbitrary units +/- SEM for eccentrically and concentrically exercised legs with whey protein (black bars) or placebo (white bars) supplementation. * designates a difference compared to pre-habituation basal, p<0.05. # designates a difference compared to pre- and post-habituation basal, p<0.05. $ designates a difference between concentric contraction + whey protein supplementation compared to all other combinations of contraction mode and supplement.

DISCUSSION

This study is the first to investigate the acute response of STARS signaling components to resistance exercise and its sensitivity to contraction mode and/or dietary supplementation. We implemented exercise-habituation in our design, to distinguish between general stress- and exercise-responses. Our results confirm that components of the STARS pathway responds to resistance exercise, in that STARS protein expression and SRF phosphorylation increased compared to both pre- and post-habituation basal levels (although for STARS protein expression only with concentric exercise), whereas the variation for MRTF-A was dependent on time but not contraction mode. Similar to us, Wallace et al. (2011) recently observed that STARS protein expression is induced very early after single-bout endurance exercise whereas induction of pSRF occur several hours later [5]. Thus, STARS signaling may generally rely on contraction per se, but it is noteworthy that STARS protein expression exhibited sensitivity to concentric contraction and protein supplementation.

CONCLUSION

STARS signaling pathway components are upregulated with hypertrophy-inducing stimulation with no major influence of differential contraction mode or dietary supplementation type.

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ACUTE ATROGENE RESPONSE TO SINGLE-BOUT CONCENTRIC VERSUS ECCENTRIC RESISTANCE EXERCISE ± WHEY PROTEIN SUPPLEMENTATION

Renae Stefanetti[1], Kristian Vissing[2], Stine Klejs Rahbek[2], Jean Farup[2], Severine Lamon[1], Marita Wallace[1], Mikkel Holm Vendelbo[3] and Aaron Russell[1]

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INTRODUCTION

Atrogin-1 and muscle ring finger-1 (MuRF-1) are E3-ubiquitin ligases, collectively termed "atrogenes" (*1*). These proteins are key components of the ubiquitin–proteasome system, the main pathway involved in skeletal muscle protein degradation (*2*). Atrogin-1 and MuRF-1 are consistently increased during rodent skeletal muscle atrophy (*1*), but resistance exercise studies in humans have demonstrated that mRNA levels of atrogenes may be transiently up-or down regulated from 1 hour until 24 hours of recovery (3, 4); depending on the mode and intensity of the exercise as well as the training history of the subjects. However, to ascertain the implication of such findings there is a need to measure protein levels. Thus far, no acute resistance exercise studies have measured Atrogin-1 and MuRF-1 gene expression in conjunction with their protein levels. Furthermore, the effect of protein ingestion in relation to degradation during exercise has received very little attention. The aim of this study is to investigate the expression of atrogenes following a single bout of eccentric versus concentric resistance exercise combined with either whey protein or placebo supplementation.

METHODS

An unpaired, randomised, doubled-blinded trial was conducted whereby healthy untrained male subjects were randomly assigned into two independent groups (n = 2 x 12), both performing concentric exercise with one leg and eccentric exercise with the other. One group consumed a whey protein hydrolysate supplement (WPH) while the other group received a placebo (P). Habituation was achieved through a preliminary 10 day training period. This consisted of 3-4 training sessions over the 7-10 period. The final training session was conducted 3 days prior to the single-bout trial. The single-bout trial encompassed eccentric and concentric exercise assigned in a randomised order. Subjects completed 6 sets of 10 repetitions at 30° x sec^{-1} angular velocity using an isokinetic dynamometer, with 3-4 minutes rest between sets. Immediately upon exercise completion, WPH and P supplements were given as single bolus of 0.30 gr whey protein C + 0.30 gr CHO pr. kg LBM or 0.60 gr CHO pr. kg LBM, respectively. Muscle biopsies were extracted prior to and following habituation and 1, 3, and 5 hours post the single-bout trial from both legs. Atrogin-1 and MuRF-1 mRNA levels (normalised to 36B4) were measured via real-time PCR, while Atrogin-1 protein level (normalised to GAPDH) was quantified via western blotting. Effects of time, treatment and time x treatment were assessed by a 2 way repeated measures ANOVA. Interactions between variables were further examined via MANOVA or t-tests. A Bonferroni adjustment was used when performing multiple t-tests.

RESULTS

ANOVA demonstrated no interaction for supplementation x exercise x time. Consequently, data was grouped according to exercise mode and all results shown are independent of supplement type. A time effect was observed for Atrogin-1 mRNA expression, with an increase after eccentric and concentric habituation when compared to pre-habituation levels (Figure 1A). A decrease was observed at 3 and 5 hours after the single-bout exercise when compared to post-habituation levels and concentric contraction (Figure 1B). As there was no interaction for time, exercise time points were combined to report the overall affect of exercise. At the protein level, habituation to eccentric contraction lead to a decrease in Atrogin-1 protein (Figure 1C) and a decrease in 5 hours post single-bout eccentric contraction, compared to post-habituation levels (Figure 1D). Similarly to Atrogin-1, MuRF-1 transcript levels increased with concentric habituation compared to pre-habituation; no effect of eccentric habituation was observed (Figure 1E). MuRF-1 mRNA decreased at 3 and 5 hours post single-bout eccentric contraction compared to concentric contraction (Figure 1F). In contrast to eccentric exercise, MuRF-1 mRNA increased at 1 and 3 hours post single-bout concentric contraction compared to post-habituation levels.

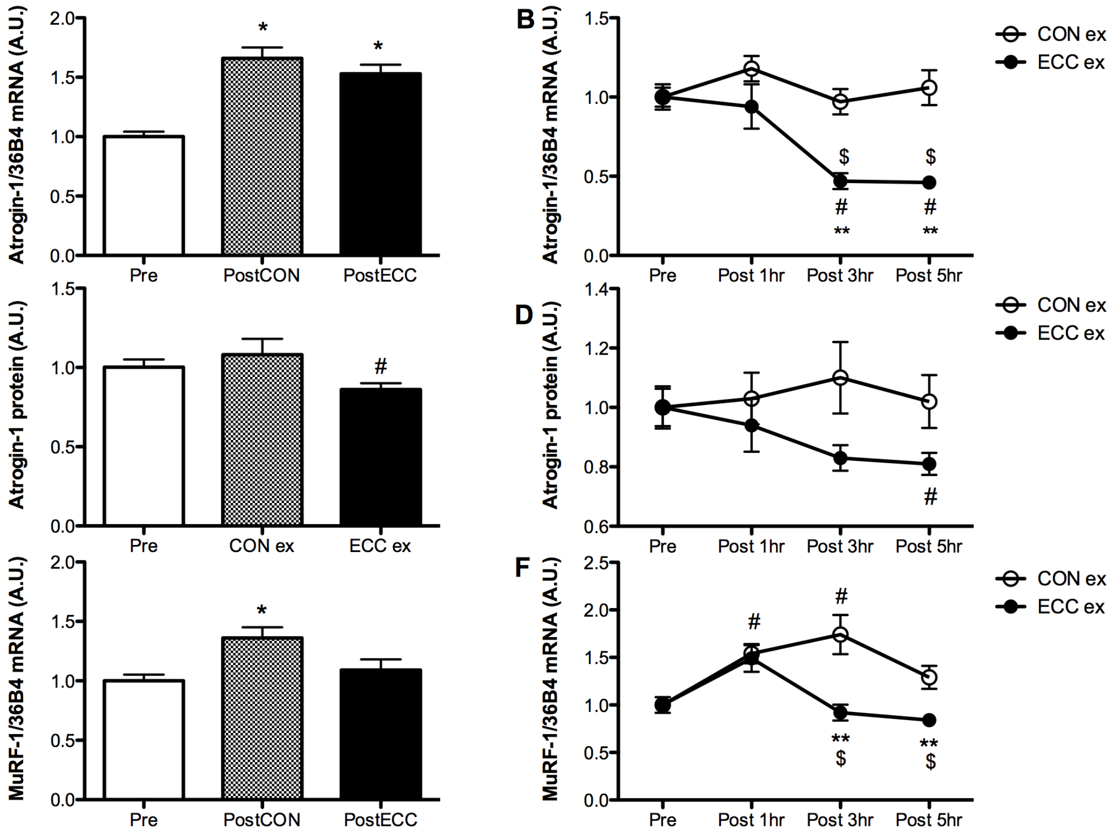

Figure 1. Atrogene response. Changes in Atrogin-1 mRNA (**A+B**), Atrogin-1 protein (**C+D**) and MuRF-1 mRNA levels (**E+F**), shown as mean arbitrary units +/- SEM for eccentrically and concentrically exercised legs * denotes a difference compared to pre-habituation basal, $p<0.05$. # denotes difference compared to post-habituation basal, $p<0.05$. ** denotes difference compared to 1 hour post single-bout eccentric contraction, $p<0.05$. $ denotes difference compared to concentric contraction, $p<0.05$.

DISCUSSION

This study employed single-bout exercise, completed after preliminary exercise-habituation, to investigate the effects of contraction mode and/or dietary supplementation on atrogene responses. Dietary supplementation combined with resistance exercise showed no effect on atrogene signalling. Exercise-habituation did regulate atrogene levels and therefore should be considered when interpreting exercise-induced responses. Single-bout resistance exercise-induced changes in gene expression observed in the present study agree with those found in previous literature (4, 5), showing that Atrogin-1 is downregulated following eccentric exercise (4), while MuRF-1 mRNA is downregulated with eccentric and upregulated with concentric contraction modes. Our study is the first of its kind to measure Atrogin-1 protein and we show that the protein levels follow a similar regulatory pattern as the Atrogin-1 mRNA.

CONCLUSION

The atrogenes, Atrogin-1 and MuRF-1 are differentially regulated following an acute bout of resistance exercise. Their regulation is dependent on exercise habituation, the type of muscle contraction and time post exercise. Their regulation is not influenced by whey protein supplementation.

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WHEY PROTEIN AUGMENTS BOTH MUSCLE AND TENDON HYPERTROPHY IRRESPECTIVE OF CONTRATION MODE FOLLOWING RESISTANCE EXERCISE TRAINING

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INTRODUCTION

Muscle protein-synthesis is instantaneously affected by protein intake following resistance exercise [1] and therefore dietary protein, rich in branched chain amino acids, such as whey protein constitutes an essential prerequisite to augment muscle growth during resistance training. The longterm effects of whey protein combined with resistance training on muscle hypertrophy are somewhat variable and the potential effect on interconnected tendon tissue is virtually unexplored. Besides protein intake the contraction mode and in particular eccentric contractions has been suggested as superior for inducing muscle hypertrophy possibly relating to the potentially higher contraction forces and lower energy cost [6]. However, modality-specific longterm resistance training studies show diverging results in relation to muscle hypertrophy [6] and the effect of modality-specific resistance training on tendon hypertrophy is, to the best of our knowledge, unknown. In a comparative study we aimed at investigating the effect of maximal isolated isotonic eccentric or concentric training combined with either a whey protein or a isoenergetic placebo supplement on muscle and tendon hypertrophy.

METHODS

24 subjects (mean±SEM; height 181.5±1.5 cm, weight 78.1±1.8 kg, age 23.9±0.8 years, fat% 16.0±0.9%) were randomly allocated into either a whey protein group (WHD, n=12) or carbohydrate placebo group (CHO, n=12). All subjects performed isolated knee extensions with one leg performing eccentric contractions and the other performing concentric contractions. Subjects completed 33 training sessions of isotonic knee extensions (6-12 sets x 15-6 repetitions equal to repetition maximum loading) during 12 weeks. Immediately following training sessions, the subjects ingested a drink consisting of 19,5 g whey protein + 19,5 g of carbohydrate (WHD) or 39 g of carbohydrate (CHO). Before and after training, the cross-sectional area (CSA) of m. quadriceps [obtained at 1/2 and femur lenght] and patella tendon [obtained at distal, mid and proximal level of patella tendon lenght] was obtained by MRI scannings in accordance with previous studies [5]. Total training load was calculated as load x repetitions x sets for all conditions. The difference in load between contraction mode was examined using a paired t-test. The effects of time, supplement and/or contraction mode on quadriceps and patella tendon CSA were assessed using a two-way ANOVA with repeated measures for time (accounting for repeated nested measures on each subjects). Linear regression analysis was used to examine differences between individual conditions.

RESULTS

Two non-exercise related dropouts occurred (one from each group) before completion of the study (thus leaving n=11 for each group). In the WHD and CHO groups the load for eccentric leg was 11.0±0.8% and 10.3±0.8% higher than the concentric leg, respectively (p<0.001).

Variable		Eccentric leg			Concentric leg		
	Group	Pre	Post	Δchange	Pre	Post	Δchange
Quadriceps CSA	CHO	80.9±2.6	83.1±2.6	2.1±0.8**	79.4±2.5	82.5±2.5	3.0±0.9***
	WHD	76.6±2.7	82.9±2.7	6.3±0.9***	77.8±2.6	82.5±2.6	4.6±0.7***
Proximal patella tendon CSA	CHO	1.38±0.06	1.49±0.06	0.12±0.06 *	1.40±0.05	1.49±0.07	0.09±0.06
	WHD	1.55±0.11	1.78±0.14	0.23±0.07 ***	1.42±0.09	1.62±0.08	0.20±0.05***

Table 1. Quadriceps muscle and patella tendon cross-sectional area (CSA, cm^2) pre and post modality-specific resistance training, with either whey protein or placebo supplementation. Data are shown as mean ± SEM. Significant difference change from pre are denoted by * (p<0.05) , ** (p<0.01) or *** (p<0.001)

Absolute CSA changes are displayed in Table 2.Quadriceps CSA increased by 8.3±1.3% and 6.2±1.4% ($p<0.001$) in WHD and 2.7±1.1% ($p<0.01$) and 4.0±1.0% ($p<0.001$) in CHO, for the eccentric and concentric leg, respectively. The increase in WHD was greater compared to CHO ($p<0.01$) (**Fig1-A**). Proximal patella tendon CSA increased by 14.9±4.8% and 14.9±4.1% ($p<0.001$) in WHD and 9.7±5.1% ($p<0.05$) and 6.5±4.1% (ns) in CHO, for the eccentric and concentric leg, respectively. A tendency to group x time effect ($p=0.054$, **Fig1-B)** was observed towards a greater increase in patella tendon CSA with WHD compared to CHO (14.9±3.1% vs 8.1±3.2%). There was no effect of contraction mode on muscle or tendon CSA.

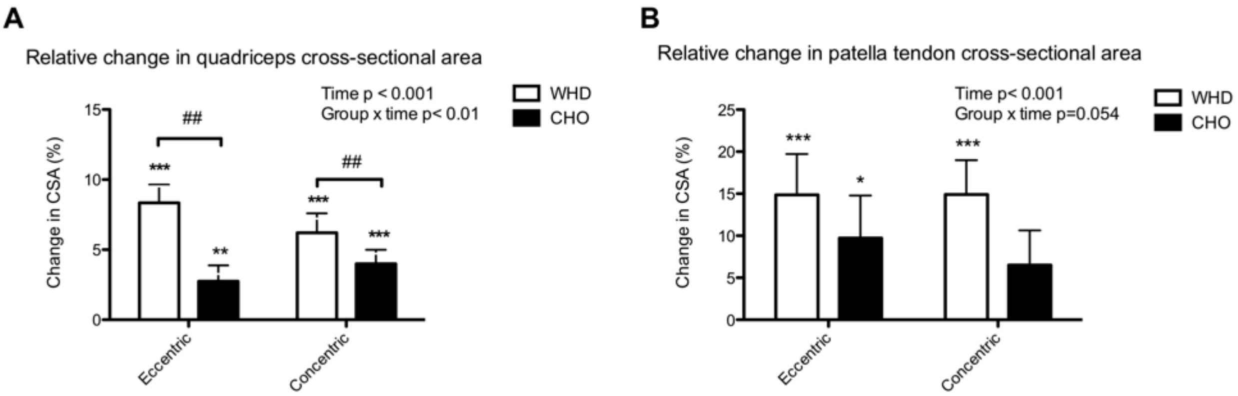

Fig 1. Relative changes (%) in quadriceps muscle CSA (**A**) and proximal patella tendon CSA (**B**). Data are shown as mean ± SEM. Changes from pre are denoted by * ($p<0.05$), ** ($p<0.01$) or *** ($p<0.001$). Differences between groups are denoted by ## ($p<0.01$).

DISCUSSION
The primary findings of this study were; 1) that resistance training-induced muscle and tendon hypertrophy can be augmented with a whey protein supplement compared to a isoenergetic supplementation – irrespective of contraction mode and; 2) that this hypertrophy-response seems irrespective of contraction mode. The greater increase in muscle CSA with whey suplementation is in agreement with our initial hypothesis and also some previous studies [1, 4]. On the other hand, some studies have failed to show these effects [3, 7]. The novel finding of an tendency towards greater increase in patella tendon CSA in the WHD compared to CHO group is intriguing and could possibly be explained by the potential effect of leucine on collagen synthesis [2] considering the high leucine content in the whey supplement (16.8%) used in this study. Despite using maximal loading in both the eccentric and concentric leg we observed virtually identical increases in muscle and tendon CSA which could indicate that no single contraction mode is primary responsible for inducing a hypertrophic response in muscle and tendon tissue, or at least not with isotonic exercise training.

CONCLUSION
Whey protein augments muscle and tendon hypertrophy following 12 weeks of resistance training – irrespective of contraction mode.

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THE EFFECT OF A VITAMIN C+E SUPPLEMENT AND A COMBINED OMEGA-3 AND PROTEIN SUPPLEMENT ON RECOVERY FROM A BOUT OF RESISTANCE EXERCISE

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INTRODUCTION

The generation of free radicals (RONS) in the working muscles during resistance exercise seems to be important for cell signalling and the concomitant increase in rate of protein synthesis (Jung et al., 2003; Niess & Simon, 2007). Consequently, intake of high dosages of antioxidants may inhibit muscle growth by reducing the oxidative stress during exercise. On the other hand, increased intake of antioxidants may reduce some of the negative stress on muscle structures and thereby increase the rate of recovery (Allen, Lamb, & Westerblad, 2008). In this study we investigate some of the acute effects of vitamin C and E on cell signalling and recovery from a single bout of resistance exercise.

METHODS

Twenty-one subjects (11 men and 10 women; 27±7 years) were recruited from an on-going 10-week strength training intervention with vitamin C and E, a combined ω -3 and protein beverage or placebo supplementation. Fatigue and recovery of muscle force-generating capacity were measured by maximal voluntary isometric contractions (MVIC, knee-extension) before (-15 min) and 15 min, ~3 h and 24 h after a bout of 4x10RM sets of leg press and knee-extension (1 min between sets, 3 min between exercises). 500 mg vitamin C and 117.5 mg vitamin E, the combined omega-3 and protein beverage (700 mg of ω-3, 7 g of whey protein, 1000 mg of β-alanine, 1.3 µg of vitamin D, and 22 g of carbohydrates) or placebo supplements were taken 3 h before exercise and again halfway into the exercise bout. Biopsies were collected twice before exercise (pre 1 and 2, together referred to as pre) and 100 and 150 min after exercise (post 1 and 2, together referred to as post). Phosphorylation of p70, RPS6, eEF2 and PRAS40 were measured by western blotting.

RESULTS

No group differences were found in the recovery of MVIC after the exercise bout. MVIC was decreased by 15-20% and recovered to 6-3% below baseline 24 h after exercise in all groups (fig. 1).

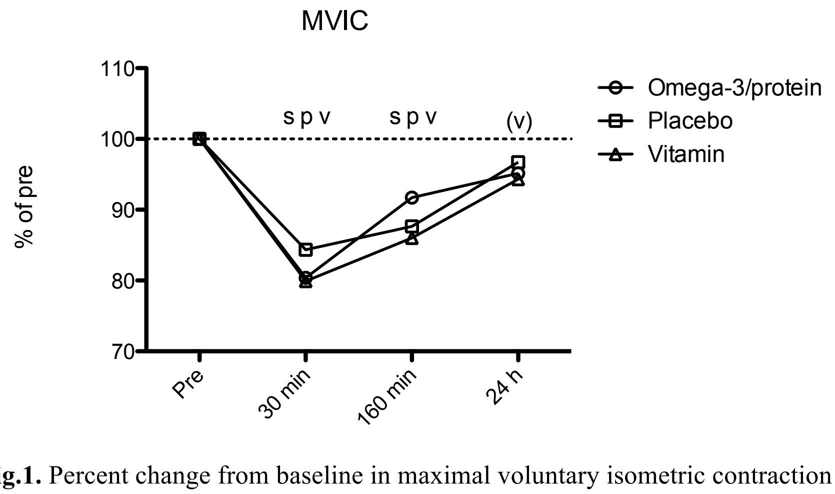

Fig.1. Percent change from baseline in maximal voluntary isometric contraction (MVIC) for each group at 30 min, 160 min and 24 hours after the beginning of exercise. Lower case letters indicating significantly different from baseline (p=0,05), s = ω -3 and protein beverage, p = placebo and v = vitamin. () Indicates tendency (p<0.1).

Phosphorylation of p70 increased from pre to post exercise in the groups receiving the combined omega-3 and protein beverage (115±92%, p<0.01) and placebo (129±77%, p<0.01), but showed only a tendency towards increase in the vitamin group (47±56%, p=0.07, fig 2, left panel). The increase from pre to post in the vitamin group was significantly smaller than in the placebo group (p<0.05). Phosphorylation of rps6 increased post exercise in the vitamin group (92±88%, p<0.05) and tended to increase in the combined omega-3 and protein beverage group (116±163%, p=0.08), but did not change in the placebo group which had a significantly smaller response compared to the combined omega-3 group (p<0.05, fig 2, right panel).

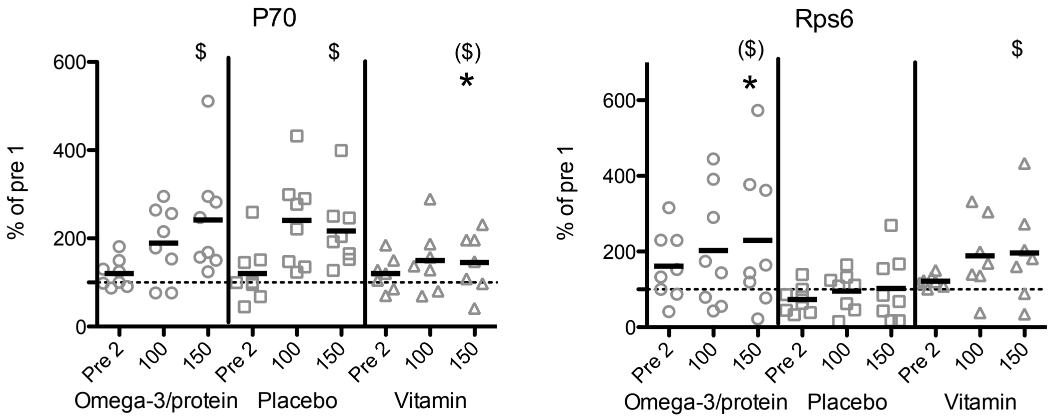

Fig.2. Percentage change from pre 1 in phosphorylation of p70 (left panel) and rps6 (right panel) for each subject at pre 2, 100 min and 150 min after the of beginning of exercise. $ Indicate significantly different from pre 1 at post (ttest, p=0,05) * Indicate significant difference from Placebo (ANOVA with bonferoni, p=0.05, () indicate p<0.1.

The post exercise ratio (phosphorylated protein/total protein) of eEF-2 was reduced (increased activity) only in the vitamin group (-12±12%, p<0.05). PRAS40 showed no significant change in any of the groups or differences between the groups. However PRAS40 phosphorylation after 100 minutes and at 150 minutes correlated with the 10-week change in lean mass (0.57 p<0,01) and strength of the knee extensors (0.59, p<0,01), respectively, during the main study. After 10 weeks of strength training muscle mass and strength gains significantly increased in all groups: combined omega-3 and protein beverage 3.7%, 11.3%, placebo 1.7%, 11.8% and vitamin 2.0% and 6.3% respectively. The placebo group tended to have a greater increase in strength than the vitamin group (p=0.09).

CONCLUSION

In response to the exercise bout all groups increased the activation of p70. However, the group receiving vitamin C and E had a reduced p70 response. Surprisingly the vitamin group had a greater rps6 response compared to the placebo group. Over time these differences seemed not to result in differences in LBM accumulation, but there was a tendency towards a reduced effect on strength gains in the vitamin group.

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ADAPTATION TO EARLY MORNING VS. AFTERNOON RESISTANCE TRAINING: SKELETAL MUSCLE HYPERTROPHY AND CELL SIGNALLING

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INTRODUCTION

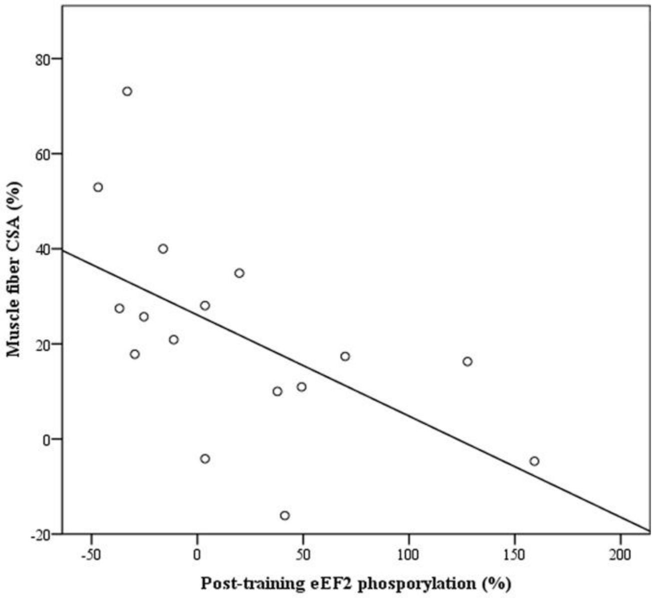
Morning neuromuscular deficit, meaning that an individual is on average 5 to 10 percent weaker compared to the rest of the day, has been repeatedly reported [1]. However, lower morning performance can be improved to the afternoon levels by regularly training in the morning hours over period of several weeks [2]. Less is known with regards to hypertrophic adaptations to resistance training in the morning vs. in the afternoon. To date, the only study performed on humans found a tendency to slightly smaller gains in muscle size when repeatedly training in the morning compared to the late afternoon [3]. One of the possible mechanisms contributing to above-mentioned time-of-day depended training adaptations, are signalling pathways involved in the control of protein synthesis. Therefore, the purpose of this study was to examine effects of the time of day on skeletal muscle hypertrophy and phosphorylation of selected proteins when resistance training was performed regularly either in the morning or afternoon.

METHODS

Twenty-two untrained men (mean ± SD, 24 ± 3 yrs, 77.4 ± 5.82kg, 181 ± 8.35cm) were pair-matched based on MVC and body mass index, and randomly divided into two time-specific resistance training groups: Morning (M) and Afternoon (A). M and A trained for 11 weeks an identical hypertrophy-type of resistance training; 2-3 sessions per week between 07:30-08:30 h and 16:00-17:00 h, respectively. In both groups all sessions were supervised. Out of 22 subjects, 11 and 7 completed the whole training period in M and A, respectively. Another 7 subjects served as controls (C). All subjects underwent an acute resistance loading protocol consisting of 5 sets of 10 repetitions of maximum isokinetic bilateral leg extensions one week prior to and one week after the training period. Thirty minutes before and sixty minutes after the acute loadings, muscle biopsies were taken from the right and left *vastus lateralis*, respectively. Specimens were later homogenized and analysed for phosphorylation of p70S6 (Thr389 and Thr421/Ser424), rpS6 (Ser240/244), p38MAPK (Thr180/Tyr182), Erk1/2 (Thr202/Tyr204), and eEF2 (Thr56) by Western blot technique and quantified by enhanced chemiluminescence method. Muscle specimens were also analysed for muscle fibre cross-sectional areas (CSA) by immunohistochemistry. Non-parametric statistical methods were used to compare relative acute changes in phosphorylation of selected proteins before and after the training period for all three groups separately. Pearson's correlation coefficient was calculated for relative changes in CSA and relative acute changes in phosphorylation of selected proteins both before and after the training period with M and A merged together.

RESULTS

The M and A group significantly increased fibre CSA from 5249±809 to 6356±1127 μm^2 (21.1%) and from 5836±1001 to 7125±1108 μm^2 (23.0%), respectively ($p<0.01$, Paired Samples T-test). Fibre CSA in the C group did not significantly change (6138±1016 to 5755±1107 μm^2, -5.9%). The Wilcoxon Signed rank test showed significant differences between pre- to post training values in M ($p=0.016$) but not in A ($p=0.128$) or C ($p=0.310$). Time-of-day specific training did not induce significant changes in acute changes of phosphorylated $p70S6^{Thr389}$, rpS6, Erk1/2 and p38MAPK. On the contrary, acute increase in $p70S6^{Thr421/Ser424}$ phospohorylation was statistically similar before training in both groups but significantly different (higher, $p=0.013$) in the M compared to the A groups after the training period. In the A group, levels of phosphorylated post-loading eEF2 were higher than in the M group ($p=0.039$) after the training period. Interestingly, statistically significant



negative correlation was found between changes in muscle fibre CSA and post-training acute changes in eEF2 phosphorylation, a protein downstream to p70S6K ($p=0.021$, $r=-0.572$, Fig. 1).

Figure 1: Relationship of relative training induced-changes in muscle fibre CSA and relative changes in eEF2 phosphorylation during post-training acute resistance loading in the training groups.

DISCUSSION

This study showed that, in general, similar levels of muscle fibre hypertrophy could be achieved regardless of which time of the day the training sessions were executed. However, we observed significantly larger variability in hypertrophic adaptation in the morning training group, in which more non-responders were present ($p=0.016$, Wilcoxon test). In addition, it is possible that, at the level of skeletal muscle signalling, the extent of adaptation in some parameters, may be time-of-day depended. After 11 weeks of training, significantly increased post-loading levels of phosphorylated p70S6$^{Thr421/Ser424}$ and lower levels of phosphorylated eEF2 in M suggest more favourable cell signalling for protein synthesis in the morning. However, it remains unknown whether this is a compensatory mechanism because e.g., many metabolic and hormonal parameters related to protein synthesis distinctly differ between morning and afternoon [5,6]. Terzis et al. [4] reported that acute post-loading increase in p70S6^{Thr389} correlated with muscle mass gained later in the training. This was not the case in the present study. Interestingly, a weak negative correlation was found between muscle mass accretion and post-training changes in eEF2 phosphorylation. It could mean that people with higher adaptation in protein synthesis translation elongation capacity after several weeks of training, also tend to gain more muscle mass, regardless of time of day. It warrants further research to confirm a causal relationship between these two parameters.

CONCLUSION

Comparable gains in lower extremity muscle fibre CSA was achieved regardless of whether training was performed in the morning or in the afternoon hours. However, some individuals may have blunted hypertrophic responses when regularly training in the morning. Protein synthesis-enhancing signalling through phosphorylated p70S6$^{Thr421/Ser424}$ and eEF2 may be somewhat improved after 11-weeks of morning sessions compared to when trainings are regularly performed in the afternoon.

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COMPARING THE EFFECTS OF 12 WEEKS OF BLOOD FLOW-RESTRICTED LOW-LOAD STRENGTH TRAINING AND 12 WEEKS OF HIGH-LOAD STRENGTH TRAINING ON STRENGTH PERFORMANCE AND MUSCLE CHARACTERISTICS IN UNTRAINED WOMEN

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INTRODUCTION

Blood flow-restricted (BFR) strength training offers an efficient low-load alternative to traditional heavy-load strength training (TRAD). It provides similar gains in strength performance[1] and does not seem to be associated with aberrant side effects[2]. While the hypertrophic events associated with TRAD are thought to be mediated by mechanical stress, the effect of BFR is thought to be mediate by metabolic stress. However, the cell biological adaptations to BFR remains elusive[3]. We are not aware of any study that has compared the effects of BFR with those of TRAD within the same person (identical genetic potential).

We hypothesized that TRAD and BFR strength training would result in similar increases in muscle strength and quadriceps cross sectional area (CSA) in untrained women. Furthermore, we hypothesized that TRAD and BFR would result in different adaptations at the level of gene expression, thereby leading to development of different molecular signatures measured as MyHC mRNA gene-family profiling.

METHODS

Nine untrained female subjects (age 22±1 years, height 169±3 cm, body weight 69±5 kg) performed 12 weeks training of unilateral knee-extension twice a week. Knee-extension 1RM was determined before and after the training period. One leg was exercised with partial BFR induced by a pressure cuff inflated to 90-100 mmHg around the proximal part of the thigh. The exercise consisted of 5 sets to failure at 30% of 1RM (45 sec rest between sets). The other leg exercised three 10 – 6RM sets of TRAD (90 sec rest between sets). For each leg, CSA of the *m. quadriceps* was assessed using MRI and muscle biopsies were sampled from the *m. vastus lateralis* prior to *and* subsequent to the training period. Muscle biopsies were homogenised and RNA was extracted using TRIzol reagent. Real-time RT-PCR to assess the expression of MyHC 1, 2A and 2X was performed as previously described [4]. Gene-family profilling was performed as previously described [5]. Analyses of MRI and real-time RT-PCR data were performed in a blinded fashion.

RESULTS

TRAD and BFR resulted in similar increases in unilateral knee-extension 1RM after 12 weeks of training (12±7 vs. 12±7%, respectively; $p \leq 0.05$, Fig 1). Moreover, both training forms resulted in increases in quadriceps CSA (8±4 vs 6±4 % $p < 0.05$), with TRAD showing greater hypertrophy than BFR ($p < 0.05$, Fig 2).

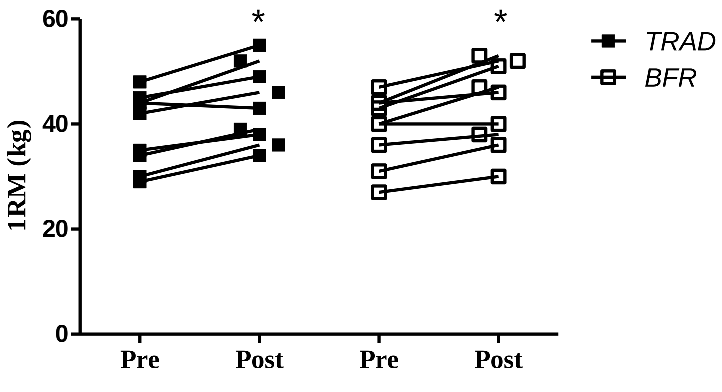

Fig. 1 Knee-extension 1RM measured prior to (Pre) and subsequent to (Post) 12 weeks of high resistance strength training (*TRAD*; black) and blood flow-restricted strength training (BFR; white). * = Sign. different from pre ($p \leq 0.05$)

The two modes of strength training resulted in alterations in the MyHC mRNA composition of *m.vastus lateralis* (Fig. 3). While TRAD resulted in increased abundance of MyHC1 mRNA compared to pre values, BFR resulted in increased abundance of MyHC2A mRNA. Both groups showed a concomitant decrease in MyHC2X mRNA abundance. Subsequent to the training period, TRAD and BFR legs showed differences in MyHC mRNA composition (MyHC1, $p<0.05$; MyHC2A, $p=0.06$). Similarly, the two training forms were found to have a large relative effect on MyHC1 abundance (ES=1.34) and a moderate relative effect on MyHC2A mRNA abundance (ES=0.89).

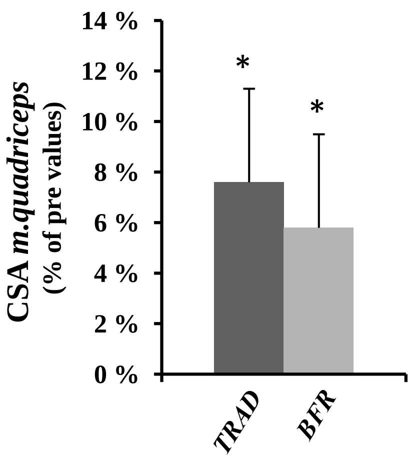

Fig. 2 Changes (%) in cross sectional area of m. quadriceps after 12 weeks of high resistance strength training (*TRAD*) and blood flow-restricted strength training (BFR); measured using MRI. * = Sign. different from pre ($p < 0.05$).

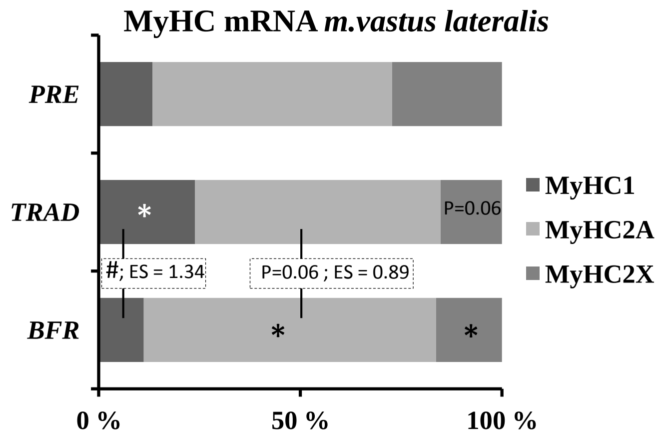

Fig. 3 Gene-family profiling of MyHC mRNA measured in biopsies from m.vastus lateralis sampled prior to and subsequent to 12 weeks of high resistance strength training (*TRAD*) and blood flow-restricted strength training (BFR). * = sign. different from pre ($p \leq 0.05$); # = sign. different between treatments ($p \leq 0.05$); ES = effect size.

DISCUSSION

This study gives support to the utilization of BFR as an effective alternative to TRAD. However, although the two modes of training resulted in similar adaptations at the level of strength performance, they were accompanied by differences at the level of *m.quadriceps* CSA adaptation and MyHC mRNA composition. This suggests that the strength adaptations may have come about through different mechanisms.

Interestingly, we recently showed that in the untrained state, both TRAD and BFR results in a αBc-response 1h after exercise [6]. While this response disappears in the BFR leg after 12 weeks of training, it remains in the TRAD leg, suggesting that TRAD continues to stress the myofibrillar structure. This is likely to be caused by the higher mechanical stress and may explain the difference found in MyHC mRNA composition between the groups.

CONCLUSION

TRAD and BFR strength training of knee extensors resulted in similar increases in 1RM strength performance in untrained women. The two modes of training were associated with dissimilar muscular adaptations at both the whole-muscle (macro) and the cellular level (micro).

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EFFECTS OF WHEY PROTEIN ON SERUM AMINO ACIDS AND HORMONES, PERFORMANCE, AND RECOVERY DURING A 12-DAY INTENSIVE TRAINING PERIOD IN POWER ATHLETES

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INTRODUCTION

Effects of strength training and protein supplementation have been studied intensively during recent years. These studies have focused mainly on one training session and untrained individuals and have shown that human body and physical performance capacity recover better during proceeding days with protein or amino acid supplementation (e.g.1). Protein supplementation has also enhanced adaptation during long-term training periods (several weeks or months) e.g. muscle hypertrophy (2). The purpose of the present study was to examine the effects of protein supplementation during one micro cycle of 12 days including three very intensive training sessions in power athletes.

METHODS

Sixteen power male athletes (sprinters and jumpers) were recruited and randomized into two groups. In the PRO group (n=8) protein intake was planned as 3.0 g/kg body mass/day so that one half of protein consumed was ingested through normal diet and the other half of protein was supplemented (whey protein) four times a day (in the morning, 30 min before exercise, 15 min after exercise and in the evening; if not exercise was performed then freely during the day). In the PLA group (n=8) protein intake was planned as 1.5 g/kg body mass/day so that all protein was ingested through normal diet, the other half of caloric intake was supplemented as a placebo drink (carbohydrate) four times a day, as in PRO. The subjects performed three typical intensive training sessions during the study period. The experimental design is shown in Figure 1.

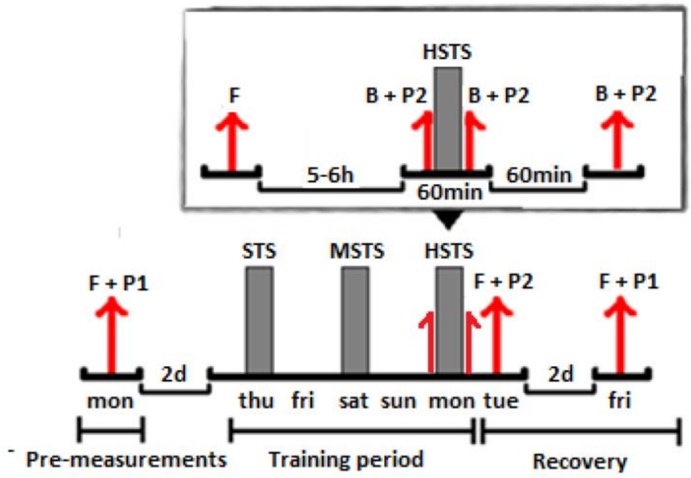

FIGURE 1. Experimental design, F=fasting blood sample (in the morning), P1=all performance measurements, P2=performance measurements without speed test, B=blood sample, red arrows= blood samples, STS=speed training session (sprint run), MSTS=maximal strength training session (leg press and power clean), HSTS=hypertrophic strength training session (leg press and power clean).

Performance measurements included maximal strength (1RM) in leg press, maximal counter movement jump (CMJ) on a contact mat and speed test indoors in a 20m run with a 10m flying start. Blood samples were drawn from an antecubital vein to analyze serum testosterone, sex-hormone-binding globulin and cortisol with Immulite 1000 analyzer and serum levels of nine amino acids with proton nuclear magnetic resonance spectroscopy (3).

RESULTS

Protein intake during the study period was 3.3 ± 0.4 in PRO and 1.6 ± 0.3 g/kg body weight/d in PLA. Branched-chain amino acids (BCAAs, Figure 2A), phenylalanine, alanine and tyrosine concentration were significantly ($p<0.05$-0.001) greater in PRO than in PLA just before, immediately after and one hour after HSTS. There were no differences in hormone concent-rations, running speed or maximal strength at any point. CMJ decreased less in PRO than in PLA after HSTS reaching statistical significance ($p<0.01$) only immediately after exercise (Figure 2B).

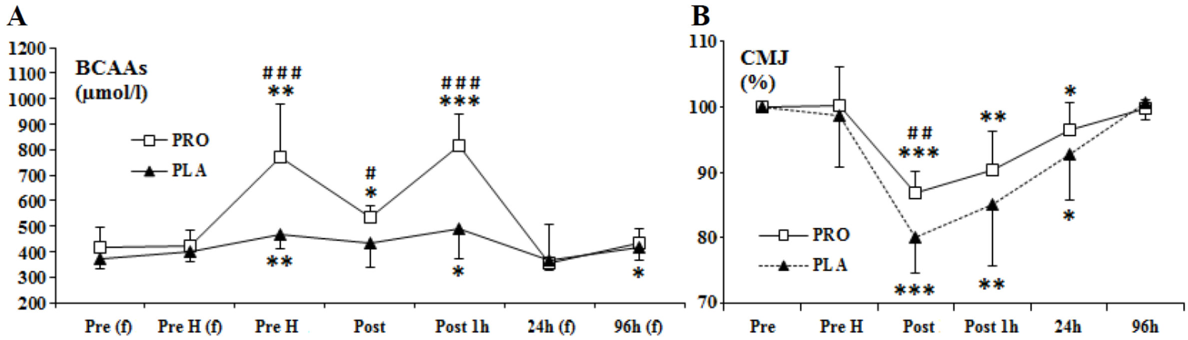

FIGURE 2. (A) BCAAs concentration before (pre) HSTS (H), immediately after (Post) and during recovery. f=fasting sample in the morning. The first Pre (f) is in the beginning of the study period and the second one is on the day of HSTS. **(B)** Relative change of CMJ before and after HSTS. **#** $p<0.05$ **##** $p<0.01$ PRO vs PLA; ***** $p<0.05$ ****** $p<0.01$ ******* $p<0.001$ **vs** Pre-value.

DISCUSSION

The present results showed that several amino acid concentrations were increased before HSTS and remained elevated after one hour of recovery. A protein dose of 27 g whey (~50% essential amino acids) was ingested 30 min before the pre-exercise measurement and 15 min after HSTS. It has been shown earlier (4) that blood amino acid concentration increases strongly 30-70 min after ingesting single amino acids or BCAAs just before the initiation of a strength training session. In the present study protein ingestion increased blood amino acids in all the exercise bouts probably both enhancing muscle protein synthesis and decreasing muscle fiber damage and finally improved the recovery process (5) after STS and MSTS. Consequently jumping ability was better after a very intensive hypertrophic strength training session when protein was supplemented. Eventually, enhanced recovery can enable greater training volume that can be speculated to lead to better adaptation and less risk for overtraining.

CONCLUSION

Protein supplementation in a micro cycle of three intensive strength and speed training sessions improves recovery from an intensive strength training session.

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ORAL PRESENTATION 2

Thursday Oct. 25th
11:30 – 13:30
(Auditorium D)

11:30 – 11:45
Marco Hagen
High resistance shank muscle strength training changes foot behaviour during a sudden ankle supination

11:45 – 12:00
Arja Häkkinen
Muscle activity during various trunk stabilizing exercises in patients after lumbar fusion surgery

12:00 – 12:15
Henrik Sørensen
Factors influencing rate of force development

12:15 – 12:30
Sanja Salaj
Bilateral deficit is dependent on speed and type of muscle contraction

12:30 – 12:45
Janne Avela
Differences in motor control between submaximal lengthening and isometric contractions of the soleus muscle

12:45 – 13:00
Martyn Beaven
Lower-body electrostimulation improves lower-body strength

13:00 – 13:15
Vesa Linnamo
Effects of aging on soleus motor unit discharge rate in dynamic movements

13:15 – 13:30
Václav Bunc
Effect of body composition on strength of upper and lower extremities in senior women

HIGH RESISTANCE SHANK MUSCLE STRENGTH TRAINING CHANGES FOOT BEHAVIOUR DURING A SUDDEN ANKLE SUPINATION

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INTRODUCTION

Muscle strength is discussed to be the most important contributing factor for joint stability. Therefore adequate muscle strengthening is needed for highly stressed joints, especially when these joints are instable, e.g. due to injuries. The ankle joint complex is most frequently involved in sport injuries. In numerous studies the influence of external stabilisators, e.g. braces or orthotics, has been extensively studied. Loudon et al. (2007) report on contradictory findings with respect to strength training interventions in subjects with functional ankle instability. One reason for the discordant findings should be that in all of these studies the main medio-lateral stabilizers of the foot, the pronators and supinators, were not trained within the functional anatomic plane which is given by the subtalar joint axis identified by Inman (1976). Purpose of this study was to identify the morphological and biomechanical effects of functional pronator and supinator strength training. It was hypothesized that this specific training will increase the muscle thickness of the peronei muscles which might enhance the muscular control of the ankle joint complex. This might be beneficial for the foot behaviour during a sudden supination.

METHODS

In a first step a functional anatomic foot strength training machine (FSTM) was constructed. It consisted of a foot apparatus whose movement axis was orientated in parallel to the subtalar joint axis which deviated about 23° to medial and about 42° to dorsal from the longitudinal foot axis (Inman, 1976). The foot apparatus was connected via a driven cardan shaft and a pull rope to the weight block. A sport shoe (size US 10) was mounted onto the foot plate and the forefoot additionally fixed with a belt.

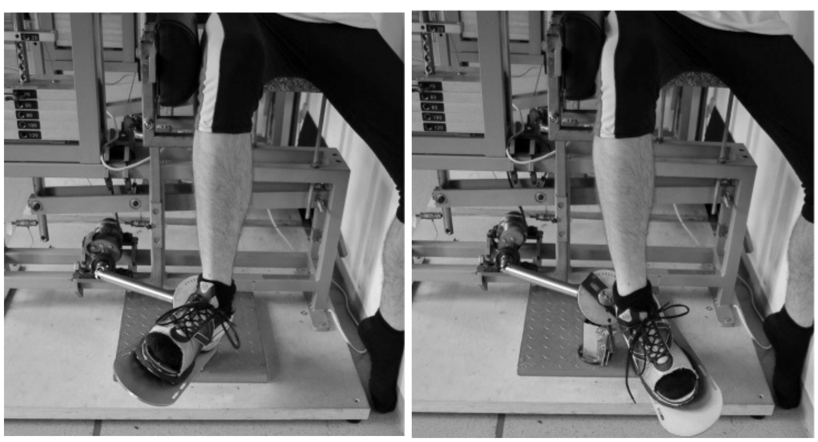

Figure 1: S Figure 1: Strength training of pronators (left) and supinators (right) at the FSTM

For the intervention study 30 healthy male sport students were randomly assigned into an experimental group (n=22) and a control group (n=8). Over a period of ten weeks the subjects went for 3 training sessions per week. In each training session single-set high resistance strength training was performed until task failure within eight to ten repetitions. The subjects of the experimental group conducted functional pronator/supinator training (FPST) at the FSTM with the right leg, the left leg was trained with plantar and dorsiflexions (PD) at traditional training machines. That way the left leg also served as intraindividual control leg. The control group performed PD with both legs. Before and after the training period every subject had to undergo muscle strength and biomechanical testing as well as muscle volume measurements. To monitor experimentally foot behaviour and muscle reaction time (EMG) during a sudden ankle term a custom made supination platform mounted on a force plate (Kistler 9281 B) was used. Supination angle was measured by using an electrogoniometer (Megatron MP 10) which was attached to the heel cap of a sport shoe. Muscular reaction of m. tibialis anterior (TA), m. peronaeuslongus (PL) and m. vastusmedialis (VM) were recorded by surface EMG electrodes (Delsys, Boston, USA). Additionally, the volume of the muscles from both lower legs was quantified by magnetic resonance images (3 Tesla MRI,) of 9 randomly chosen test persons of the experimental group. The results were analyzed by repeated measures analyses of variances (ANOVA). The significance level was set at 5%.

RESULTS

The intraindividual comparison of the right and left experimental leg (FPST vs. PD) revealed similar biomechanical effects despite specific strength increase. Compared to PD, FPST resulted in significantly higher pronator (14% vs. 8%, $p<0{,}01$) and supinator MVC (25% vs. 12%, $p<0{,}01$). During sudden inversions both, FPST and PD, resulted in reduced ($p<0{,}05$) and delayed ($p=0{,}06$) first peak vertical impact as well as reduced supination velocity ($p<0{,}01$). Muscular reaction on sudden ankle turns was faster after the training in PL ($p<0{,}01$) and TA ($p<0{,}05$) whereby the intraindividual comparison revealed an interaction trend in favour of FPST in PL ($p=0{,}06$).

MRI recordings showed statistical trends in training specific muscle volume increase of m. tibialis posterior (+10%; FPST vs. PD: $p=0{,}2$) and m. flexor hallucislongus (+6%; FPST vs. PD: $p=0.09$) after FPST. PL, TA and m. gastrocnemius showed significant muscle volume increase independent on the training method. No leg dominant effects in any outcome measures were observed in the control group.

DISCUSSION

Contrary to our hypothesis both, FPST and PD induced strength gains stiffened the ankle joint complex and increased lateral stability. After both, FPST and PD the ankle joint complex is more functionally stabilized against sudden supinations (reduced and delayed peak vertical force, reduced supination velocity). It can be assumed that the main training effects result in higher mechanical joint stability due to muscle volume increase. Hence, myofibril proliferation (MacDougall, 1986) results in a higher number of titin-myosin-units as well as a higher potential of resting cross bridges in terms of short range elastic component (Hill, 1968). These effects might stiffen the ankle joint complex mechanically. Training-induced reduction of supination velocity during sudden ankle terms support this thesis. Reduced reaction times in TA and PL may be a consequence of faster mechanical transfer of tendon stretch due to higher tendon stiffness and/or however, changes in synaptic plasticity of the motoneuron pool (Bawa, 2002).

CONCLUSIONS

The findings reveal that ankle stability can be influenced by enhanced muscular capacity after strength training. Both training methods, FPST and PD, are recommended for enhancing lateral stability. Because of the pathophysiology of a typical ankle sprain mechanism (plantarflexed and supinated foot in a landing maneuver), a combination of dorsiflexor and subtalar joint specific pronator strength training might show even higher functional ankle stability. Although a typical ankle sprain might not be prevented when the foot is once turned laterally during a landing maneuver the higher mechanical stiffness in dorsiflexion/pronation direction changes the foot behaviour and therefore the risk of an injury. Future clinical studies might show the preventive potential of shank muscle training.

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MUSCLE ACTIVITY DURING VARIOUS TRUNK STABILIZING EXERCISES IN PATIENTS AFTER LUMBAR FUSION SURGERY

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INTRODUCTION: Several studies have reported atrophy of multifidus muscles after lumbar spine fusion (LSF) (Hyun et al. 2007, Motosuneya et al. 2006). In addition to prolonged limited physical activity level prior to surgery detachment and prolonged retraction of the muscles may increase intramuscular pressure of erector spinae muscles causing ischemic changes (Styf and Willen 1998) and decrease in trunk muscle strength (Pradhan et al. 2002). In our previous study of 28 LSF patients the median trunk muscle force in flexion and in extension was only 21% and 11% of the force which has previously reported in healthy adults, respectively. Three months after fusion both flexion and extension force of trunk muscles increased significantly but remained to only half of the level of healthy adults (Neva et al. 2008). The purpose of the present study was to determine trunk extensor muscle activity during various trunk stabilizing exercises after LSF.

METHODS: 22 patients (50% females, mean (SD) age 59 (17) years) who had undergone LSF 3 to 11 months earlier, participated in the study. The indications for surgery were spondylolysis, degenerative olisthesis, spinal stenosis and degenerative disc disease. Bilateral surface electromyographic (EMG) activity of trunk extensor muscles (longissimus at the L1 level and multifidus at L5) was measured and raw EMG signal was rectified and averaged. 10RM values were measured during dynamic upper limb exercises (bilateral shoulder flexion and extension; horizontal shoulder adduction and abduction in the standing position). The load was individually adjusted so that each subject was able to perform 10 repetitions per set. In addition, lower limb exercise (right hip extension in the four-point kneeling position) using submaximal 10 repetitions and static back extension exercise (Modified Roman chair, similar to the Biering-Sorensen test position) were studied. The starting and finishing points of the fifth repetition in the upper and lower limb exercises were determined from simultaneous EMG and video analysis, and this period was used for analysis. In the Roman chair exercise the first three seconds was taken to the analysis. The reference EMG activities were obtained during the maximal voluntary isometric trunk extension strength action (reference value) (measured by the trunk dynamometer in a standing position) and used to normalize the EMG-activation levels collected for the present trunk muscle exercises. The intensity of back and leg pain during the past week and during the exercises were assessed by visual analogue scale (VAS, 0-100).

RESULTS: Mean (SD) maximal trunk extension strength was 341 (204) N. The highest relative activation in the longissimus muscle was measured during the Roman chair exercise (Table 1). The right and left side activities were 104% and 83% when compared with the reference values. The corresponding values during bilateral shoulder flexion were 65% and 62%. The highest activity levels of the multifidus (62 % on the right side and 64% on the left side) were measured also during the Roman chair exercise. The right and left side activity levels of multifidus were 55% and 52% during bilateral shoulder flexion and 34% and 27% during right hip extension exercise. During unilateral horizontal shoulder abduction and adduction exercises as well as during hip extension the average muscle activation levels remained under 50% of the reference values. The average intensities of back and leg pain during past week were 19 (19) mm and 15 (20) mm, respectively. During the present trunk stabilizing exercises mean (SD) back pain varied from 16 (26) mm during the Roman chair exercise to 3 (8) during horizontal shoulder abduction.

Table 1. Muscle activation during stabilizing back exercise

	Longissimus % EMG during MVC (SD)		Multifidus % EMG during MVC (SD)	
	Left	Right	Left	Right
Modified Roman chair	83 (33)	104 (63)	64 (33)	62 (37)
Bilateral shoulder flexion	62 (30)	65 (33)	52 (29)	55 (33)
Bilateral shoulder extension	26(12)	32 (18)	29 (17)	26 (20)
Horisontal shoulder abduction	26 (12)	33 (14)	24 (15)	21 (16)
Horizontal shoulder adduction	21 (10)	16 (8)	16 (10)	18 (12)
Right hip extension	35 (30)	43 (31)	27 (20)	34 (26)

DISCUSSION: Electromyography has been used to determine the extent of muscle activity during traditional trunk muscle exercises. These exercises are often performed in a supine hook lying, prone and side-lying positions (Arokoski et al. 2001, Davidson and Hubley-Kozey 2005). In core muscle exercises, the emphasis should be on training muscle activation in functional positions and motions. The selection of appropriate exercises is essential part of the planning of the rehabilitation or performance enhancement programs. The aim of the present exercises was to (i) produce load for trunk muscles in functional positions, but at the same time (ii) to prevent rotation of the trunk in the sagittal and transverse planes and (iii) to maintain the neutral position of the lumbar spine. By trunk muscle loading via the weight of the upper body the Roman chair exercise elicited the highest longissimus and multifidus muscle activity. Bilateral shoulder flexion exercise in the standing position also elicited the level of muscle activity that may be high enough to develop muscle endurance and strength characteristics, while in the other exercises the muscle activation levels remained rather low when using the 10-repetition principle. On the other hand, all studied exercises were feasible in the post-operative rehabilitation after lumbar fusion surgery, because pain intensity during the present exercises remained at a relatively low level.

CONCLUSION: Modified Roman chair and Bilateral shoulder flexion exercises elicited muscle activity that may be high enough to develop trunk extensor muscle endurance and strength characteristics, while in other exercises activity levels remained low. However, all exercises were safe and feasible and can also be carried out at home after lumbar spine fusion.

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FACTORS INFLUENCING RATE OF FORCE DEVELOPMENT

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INTRODUCTION

In explosive type movements, the available time for muscles to develop force typically varies between 50 and 250 ms. As the time from rest required by a muscle to develop maximal force typically exceeds 300 ms, muscle force will be at submaximal levels during many explosive type movements [1,2]. Thus, muscles' rate of force development, i.e. how fast the force increases, becomes important for optimal performance.

RFD can be quantified as time to reach a certain force, or (inversely:) force reached after a certain time, or (closer to the rate concept:) slope of the force-time curve. Furthermore, in either of these cases, force can be expressed in newton or normalised to the force during a maximal voluntary contraction (MVC), which corre-sponds to absolute and relative RFD, respectively.

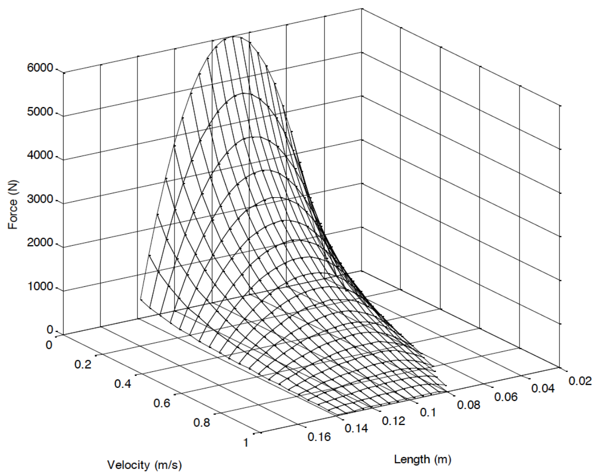
Investigations into which underlying neuro-mechanical muscle properties determine RFD are typically de-signed as longitudinal strength training studies [e.g. 1-3] or as cross sectional comparisons of MVC vs. elec-trically elicited twitch contractions [4,5] or of athletes vs. untrained subjects [5]. These authors generally agree that strength training increases absolute RFD and is higher in athletes than in ordinary subjects, but disagree with respect to the underlying mechanisms. [1] ascribe the increased RFD to increased neural drive (amplitude and rate of development of the surface electromygraphical (EMG) signal), while [4] suggest that early (before ~50 ms) and late (after ~100 ms) RFD is determined by the relative amount of type IIx fibres and MVC, respectively. [5] agree with [1] that early RFD is determined by neural drive, while [3] agree with [4] that late RFD is determined by MVC. With respect to relative RFD, [1] and [5] again agree that early RFD is determined by neural drive, while [3] suggest it is determined by relative amount of type IIx fibres.

Thus, the underlying neuro-mechanical parameters suggested to influence RFD are neural drive, MVC and relative amount of type IIx fibres. Slightly simplified, status in the literature seems to be that early RFD is determined by either neural drive or relative amount of type IIx fibres, while late RFD is determined by ei-ther neural drive or MVC.

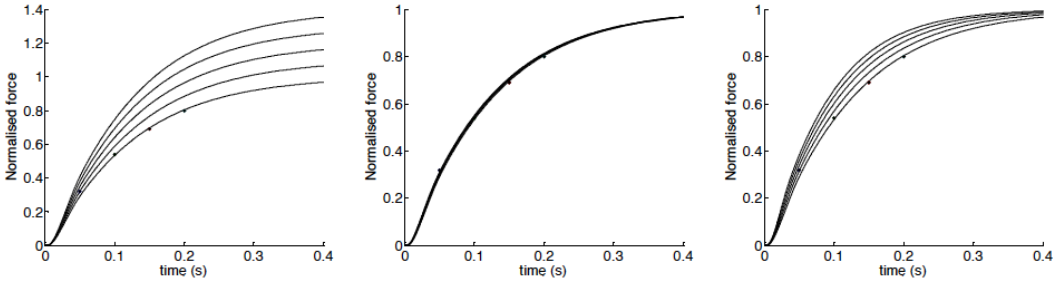
These disagreements in the literature can, to a certain extent, be ascribed the difficulties in measuring and/or controlling the various neuro-mechanical parameters in an experimental model. A computer simulation mod-el, on the other hand, offers full control over these parameters. Thus, the purpose of this study was to develop and utilise a computer simulation model of isolated knee extension in order to investigate the influence of se-lected neuro-mechanical parameters on RFD.

METHODS

We developed a computational knee extension model actuated with a single Hill-type muscle model (m. quadriceps), comprising a contractile and a series elastic element. The contractile ele-ment had force-velocity and force-length proper-ties, parameterised by F_0 (maximal isometric force at optimal fibre length) and v_0 (maximal unloaded shortening velocity). Activation dy-namics was implemented as a first order system relating bang-bang stimulation to activation, governed by a time constant τ. With less than full activation, the force-length-velocity surface (Figure on the right) was scaled down according-ly. The model was implemented in MATLAB (The MathWorks, Natick, MA) and parameter values were obtained from the literature and tuned to fit experimental, isokinetic force-velocity and RFD measurements from the literature. We used the model to measure RFD during simulated, isometric knee ex-tensions while systematically varying F_0, v_0 and τ, using a first order Euler integration algorithm with 5·10-6 s time step.



RESULTS



From left to right, graphs show RFD with F_0 increased, v_0 increased and τ decreased, respectively, in steps of 10% rela-tive to baseline (lowest) curve; black dots are read off [1] and were used to tune baseline τ.

DISCUSSION

A computer model must be validated to provide confidence in its results being transferable to the modelled, biological system. We validated our model by having it perform maximally fast, unloaded knee extensions and found it to perform in excellent agreement with experimental studies from the literature.

The physiological sequence determining rate of force development from the onset of neural stimulation of the muscle (defined as when EMG rises above resting level) can be understood as comprising activation and contraction. Activation develops the muscle's active state [6], defined as the relative amount of troponin-C bound calcium ions (Ca++). Activation comprises a number of steps with different rates, e.g. how fast the en-tire muscle becomes maximally stimulated (rate of EMG development (RED), how fast the signal spreads to the interior of the muscle (t-tubili and sarcoplasmatic reticuli (SR)), how fast Ca++ efflux from the SR causes cytosolic Ca++ concentration to rise, etc., but considering that active state becomes maximal almost instanta-neously during supramaximally stimulated twitch contractions [7], it is reasonable to assume RED to be rate limiting during activation; thus, our activation dynamics time constant, τ, represents RED.

Contraction causes force development by the pulling action of the muscle's contractile elements (CE, actin-myosin complex) on the series elastic elements (SEE, tendons, aponeuroses and other elastic connections in series with the contractile elements). The rate of this pulling action is determined by how fast the CE can pull at any given opposing force from the SEE, which is expressed in the concentric force-velocity relation, de-scribed by [1]'s hyperbolic equation $F = (F_0b-av)/(v+b)$, parameterised by the maximal isometric force, F_0, and the shape constants a and b, from which the maximal unloaded shortening velocity, v_0, can be deter-mined. F_0 corresponds to MVC and is primarily determined by the muscle's physiological cross sectional ar-ea, PCSA, and neural drive (amplitude, not RED), while v_0 primarily is determined by cross bridge cycling rate and hence muscle fibre type [1,8]. Graph A above shows RFD to increase with increased MVC, which is in accordance with the general agree-ment in the literature, given that neural drive amplitude, not RED, must be considered integral to MVC. Graph B shows RFD to increase with increased relative amount of type IIx fibres; the perpendicular distance between the curves are more or less constant throughout, making the RFD increase relatively larger early. This is in accordance with [3,4], but in disagreement with [5], who claimed intrinsic contractile factors did not influence RFD. Graph C shows RFD to increase throughout with increased RED, which is in accordance with [1,5]; [5] only found early RFD to be influenced by neural drive, which could be explained by our results, where the absolute increase is more or less equal throughout, hence relatively larger early.

CONCLUSION

RFD is determined throughout by MVC, relative amount of type IIx fibres and RED, with the two latter fac-tors' influence being relatively larger early than late.

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BILATERAL DEFICIT IS DEPENDENT ON SPEED AND TYPE OF MUSCLE CONTRACTION

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INTRODUCTION

Muscle torque generated by simultaneous two-limb contraction is lower compared to sum of individual one-limb contraction. This bilateral torque deficit (BLD_T) is not specific to subject's gender, size of muscle group and movement pattern (1). Main goal of this study is to determine whether BLD_T is caused by altered neural activation of agonists, and particularly by reduced activation of fast motor units. Hypotheses were tested through BLD_T dependence on different type and velocities of muscle contractions.

METHODS

Twenty one physically active females (N=21; average age: 21.5yrs; height: 166.3 cm, weight: 59.1 kg, body fat: 18.2%) volunteered to participate in this study. Testing consisted of anthropometric, torque and muscle activity measurements. Torque of knee extensors and knee flexors was measured using an isokinetic dynamometer (Biodex System 4, Biodex Medical Systems, Shirley, NY, USA). Torque measurement started with maximum isometric contractions of knee extensors and knee flexors. These maximum isometric efforts were used for normalization purposes as well. Isokinetic testing consisted of maximum consecutive extension-flexion cycles performed at the angular velocities of 60, 180 and 300°/s. Eccentric testing trials were performed at angular velocity of 60°/s. Bilateral torque deficit was calculated from mean peak torque values in unilateral and bilateral conditions in all contractions using following equation (2): $\mathbf{BLD_T = (100 \times (T_{BL} / T_{UL}) - 100)}$ where T_{BL} indicate the respective peak torque values during the bilateral task and T_{UL} indicate the respective peak torque values during the unilateral task. Preparation of the skin surface and electrode placement for EMG measurement were conducted according to SENIAM reccomendations. Electrodes (Noraxon dual electrode, Noraxon inc., Scottsdale, USA) were placed over the *vastus lateralis*, *vastus medialis* and *biceps femoris* (long head) of both legs. EMG signals were sampled at 4000Hz using an eight-channel telemetered system (Telemyo2400T G2, Noraxon, USA). EMG signals were processed and analysed using custom software programmed in LabView v.6.1 (National Instruments Corp, Austin, Texas, USA). Each muscle's normalized RMS values were used for bilateral EMG deficit calculation. Following equation was used: $\mathbf{BLD_{EMG}\ (\%) = 100\ [(RMS_{LL\text{-}BL} + RMS_{RL\text{-}BL}) / (RMS_{LL\text{-}UL} + RMS_{RL\text{-}UL})] - 100}$ where RMS_{LL} and RMS_{RL} indicate the respective RMS values of left and right leg during the UL and BL tasks (3). All statistical analyses were performed using STATISTICA 7.0 (StatSoft, Tulsa, OK). Differences in size of bilateral deficit at three angular velocities and three types of muscle contractions (separately for knee extensors and knee flexors) were determined using ANOVA. Level of significance was set at $p < 0.05$.

RESULTS

Bilateral deficit's dependence on speed of contraction

Significant differences were found between knee extensors and knee flexors BLD_T at different muscle contraction velocities ($p < 0.01$) (Figure 1). As the angular velocity increased, BLD_{EMG} numerically decreased in *m. vastus lateralis*, but the differences in BLD_{EMG} at different angular velocities were not significant. In *m. biceps femoris* difference between bilateral deficits at 60°/s and 300°/s angular velocities was confirmed in BLD_{EMG} results ($p < 0.05$).

Bilateral deficit's dependence on type of muscle contraction

Significant differences were found in BLD_T of knee extensors and knee flexors at muscle contractions of different type ($p < 0.05$)(Figure 2). BLD_{EMG} of knee extensors shows similar tendency: BLD_{EMG} of *m. vastus medialis* during eccentric contraction is different u from that in isometric (p = 0,063) and concentric (p = 0,054) muscle activities. BLD_{EMG} of *m. biceps femoris* in eccentric contractions is significantly different from isometric muscle conditions ($p < 0.05$).

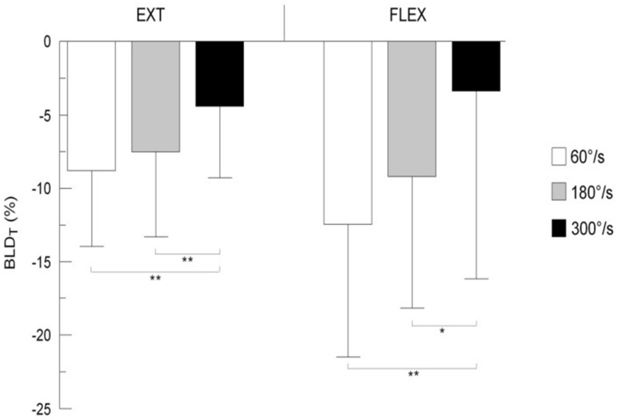

Figure 1. Values of bilateral deficit in force (BLD_T) at at 60, 180 and 300°/s angular velocities of knee extensors and knee flexors (EXT – knee extension, FLEX – knee flexion, VL – *m. vastus lateralis*, VM – *m. vastus medialis*, BF – *m. biceps femoris*, ** $p < 0.01$; * $p < 0.05$).

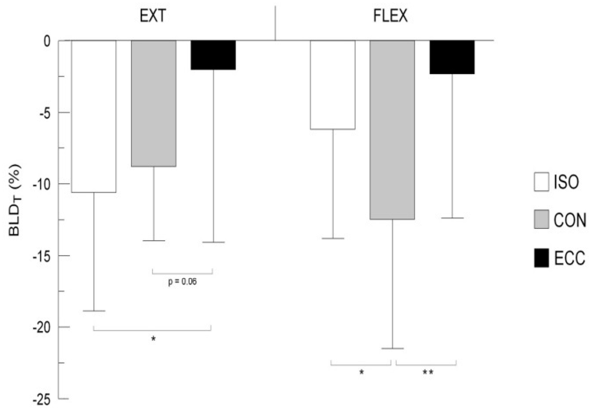

Figure 2. Bilateral force deficit (BLD_T) of knee extensors and knee flexors in isometric (ISO), concentric (CON) and eccentric (ECC) conditions (EXT – knee extension, FLEX – knee flexion, VL – *m. vastus lateralis*, VM – *m. vastus medialis*, BF – *m. biceps femoris*, ** $p < 0.01$; * $p < 0.05$).

DISCUSSION

Main results of this study show that BLD is an inhibitory phenomenon with neural background. BLD is found in isometric and concentric contractions at different angular velocities. BLD_T was confirmed through EMG analysis. Further, BLD (and EMG) was dependant on angular velocity; higher BLD_T values were found at lower velocities, and lower BLD_T values were found at higher velocities. In eccentric contractions BLD_T (and BLD_{EMG}) was not present. Parralel results of that in torque (or tendency) were found in BLD_{EMG} of knee muscles in different contractions. Previous studies on BLD showed conflicting results, it was not always studied using EMG, and the problem was not studied in different muscle contractions. Parallel results in BLD_T and BLD_{EMG} would imply that BLD_T in knee movements is caused by some kind of neural inhibition. Only two studies on BLD_T in knee extensions confirmed torque BLD_T with BLD_{EMG} (4, 5). In other, a) BLD existed but BLD_{EMG} was not measured, or b) BLD_T and/or BLD_{EMG} were not determined. Results of our study showed parallel presence and changes of BLD_T and BLD_{EMG} in analysed muscle contractions. These results suggest that BLD is an inhibition phenomenon that has neural source. Results of this study suggest that BLD is not caused by reduced activation of fast motor units. BLD was low in fast contractions and absent in eccentric ones. One of first studies on BLD (5) determined higher BLD in faster (compared to slow) leg extensions. As speed increases, so does the number of active fast motor units in torque production (6). If reduced activation of fast motor units is responsible for BLD_T, BLD_T should be highest in fast contractions, where fast motor units are dominant in force production. This was not confirmed by our study or several others (2, 7, 8). Due to selective activation of fast motor units in eccentric contractions (9), if BLD_T is caused by reduced activation of fast motor units in bilateral contractions, BLD_T would be highest in eccentric conditions. In this study, this was not the case.

CONCLUSION

To conclude, this study shows that BLD_T is an inhibitory phenomenon caused by neural inhibition and that it is not caused by reduced activation of fast motor units because: a) BLD_T in fast contractions was not the highest, b) BLD_T did not exist in eccentric contractions, c) BLD_T was comparable in fast and slow muscles, and d) median frequency was equal in bilateral and unilateral contractions.

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DIFFERENCES IN MOTOR CONTROL BETWEEN SUBMAXIMAL LENGTHENING AND ISOMETRIC CONTRACTIONS OF THE SOLEUS MUSCLE

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INTRODUCTION

Numerous studies have shown that force production capabilities of a muscle differ in lengthening (LEN) contractions as compared to isometric (ISO) or shortening ones (e.g. Komi et al. 2000). As a corollary, it has been suggested that a unique neural control scheme is elaborated by the central nervous system in the case of LEN contractions (e.g. Enoka 1996). Thus, the aim of this study was to assess possible differences in motor control between submaximal LEN and ISO contractions of the soleus muscle (SOL).

METHODS

Motor evoked responses to transcranial magnetic stimulation (MEP) and electrical stimulation of the peripheral nerve (M-waves and H-reflexes) where recorded at rest and during LEN and ISO contractions of the SOL at 20%, 40%, 60% and 80% of maximal voluntary contraction (MVC). Torque and background EMG amplitudes were averaged over a time window of 100ms prior to stimulation.

RESULTS

MEPs were found to be significantly lower ($P < 0.05$) during LEN as compared to ISO contractions at 40%, 60% and 80% MVC (10.95 ± 0.05 mV *vs* 9.93 ±0.06 mV ; 10.47 ± 0.07 mV *vs* 9.7 ± 0.08 mV; 11.48 ± 0.08 mV ± *vs* 10.14 ± 0.07 mV, respectively) when absolute values were compared (figure 1). That was also the case when MEPs were normalized to corresponding maximal M-wave. H/M ratio was significantly lower ($P < 0.05$) during passive LEN (2.5 ± 1.11) as compared to passive ISO (1.4 ±0.88 mV) conditions. In an active muscle, the H/M ratio remained unchanged between ISO and LEN for all contractions strengths. No significant differences were observed in torque/EMG ratios in any of the conditions between LEN and ISO contractions.

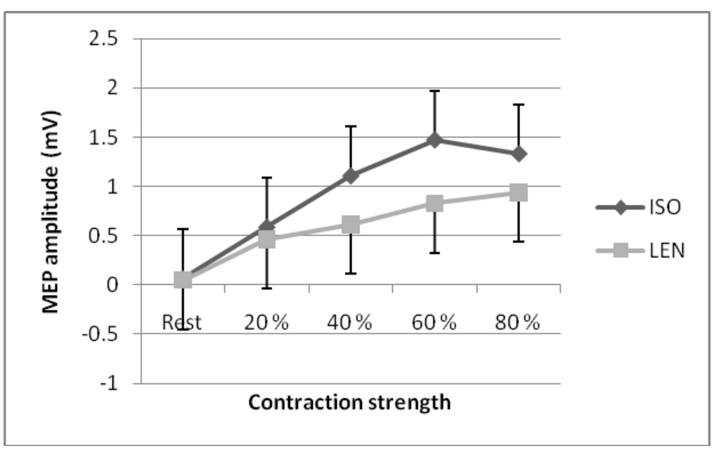

Figure 1. MEP amplitudes plotted against contraction strength for ISO and LEN contraction modes. Significant differences between ISO and LEN MEPs are depicted with asterisks. * $P < 0.05$, ** $P < 0.01$.

DISCUSSION

In the case of submaximal LEN contractions lower corticospinal excitability, as revealed by lower MEPs during the three highest force levels, was not likely to be due to any motoneuronal inhibition. This was supported by similar torque/EMG and H/M ratios between the two contraction modes.

CONCLUSIONS

It could be concluded that in submaximal contraction cortical excitability is lower in LEN as compared to ISO contractions.

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LOWER-BODY ELECTROSTIMULATION IMPROVES LOWER-BODY STRENGTH

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INTRODUCTION

Electrostimulation of the peroneal nerve (ES) has been shown to augment venous blood flow in the legs of healthy volunteers (Tucker et al., 2010). A recent study has demonstrated psychological and physiological benefits of an ES device in elite rugby players (Beaven et al., 2012). The ES device has a pulse current of 27 mA with user-adjustable pulse widths and a repetition rate of 1 Hz. Although not published, a tendency for specific strength gains were observed in this elite group. As a result, a trial was designed to examine these observations. Specifically, it was hypothesized that superior lower-body strength gains would be observed in athletes utilizing daily ES.

METHODS

Fourteen semi-professional rugby players a minimum of two years of resisted training experience (age 20 ±1 yr, height 184.1 ±4.6 cm, body mass 97.2 ±9.2 kg) were recruited. The study was approved by the ethics committee of the university. In a counter-balanced cross-over design, the players performed three weeks of upper- and lower-body resistance training (4 days a week) with a one-week washout. The intervention consisted of the use of the OnPulseTM device (FirstKind Ltd., U.K.) at the completion of each training day, while the control group wore the device but it was not turned on. Strength in the deadlift, squat, and bench press was assessed in the week prior to the trial, at the end of the third training week, and at the end of the sixth training week.

RESULTS

ES resulted in substantially larger strength increases in the deadlift (178.8 ± 19.1 to 188.4 ± 18.9 kg versus 180.9 ± 22.2 to 185.5 ± 21.6 kg; $p = 0.0004$) and squat exercises (178.9 ± 13.8 to 189.3 ± 11.9 kg versus 182.3 ± 15.0 to 188.0 ± 14.2 kg; $p = 0.0194$). There was no difference in the improvement in bench press strength between the ES and control interventions ($p > 0.05$).

DISCUSSION

An ES intervention that elicits a compression of the venous valve system within the lower leg, and has been shown to enhance both venous volume and venous velocity in the lower limb via indolent nerve stimulation, effectively increased lower-body strength gains. It is unknown whether these gains were a result of the electrically-induced contractions *per se* or improved training intensity as a result of enhanced psychological and physiological recovery reported earlier; however, the observed improvements were specific to the lower body with no effect on upper-body strength gains.

CONCLUSION

A simple and easy to use ES device was effective in improving lower-body strength gains.

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EFFECTS OF AGING ON SOLEUS MOTOR UNIT DISCHARGE RATE IN DYNAMIC MOVEMENTS

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INTRODUCTION

Aging is related to changes at the muscular level, leading to a decline in motor performance increasing the risk of falling and injury [Hamacher et al, 2011]. It seems that the age-related changes in motor unit activation are muscle- and intensity dependent. Several studies have found the elderly to have a lower motor unit discharge rate (MUDR) during high intensity contractions in muscles, like the first dorsal interosseous (FDI), tibialis anterior (TA) [Kamen et al, 1995; Klass et al, 2008] and vastus lateralis [Kamen and Knight, 2004]. In contrast, soleus MUDR was found to be lower in the elderly only at low force-levels, and no age-differences were found when comparisons were done at recruitment threshold in biceps brachii, triceps brachii, TA or FDI [Howard et al, 1988; Galganski et al, 1993]. In order understand the well known age-related changes in locomotion and balance, knowledge regarding dynamic contractions in functionally important lower-leg muscles is crucial. Thus, the purpose of this study was to examine possible differences in soleus MUDR between young and elderly adults.

METHODS

11 young males (YOUNG) (26.1±2.2yr. 1.81±0.05m 81.7±9.4kg) and 8 old males (OLD) (69.1±5.1yr., 1.69±0.04m, 75.3±6.2kg) participated in the study. The subjects performed isometric and dynamic plantar flexions while seated in an ankle dynamometer (University of Jyväskylä, Finland). The force levels studied were 10, 20, 40, 60, 80 and 100% of the isometric MVC. In dynamic condition the subjects lifted (CON) or lowered (ECC) a weight attached to the foot pedal via a cable pulley system at a voluntarily controlled velocity. The weight was adjusted so that the ankle torque during movement was identical to the corresponding ISO condition. The submaximal force levels in dynamic measurements corresponded to 10, 20 and 40% of the isometric MVC. For the intramuscular EMG recordings four separate bipolar fine-wire electrodes were inserted into the soleus muscle. Signal decomposition, motor unit identification and data analysis were performed by utilizing the three channel decomposition technique computer algorithm, “Daisy”, [Olsen et al, 2001]. For each train of motor unit discharges the inter-spike intervals were registered and instantaneous MUDR was calculated as the mean of the inverse of each inter-spike interval. The analysis of MUDR was based on 8372 motor unit discharges (YOUNG: 5772, OLD: 2600) from 210 different motor units (135 YOUNG, 75 OLD). Surface EMG activity was measured with bipolar electrodes from the soleus (SOL) and gastrocnemius medialis (GM) muscles.

RESULTS

The maximal voluntary plantarflexion force was 29.3% lower ($p<0.01$) in OLD (149.2±35.7 Nm) than in YOUNG (211.1±35.6 Nm). In isometric contractions (ISO) MUDR was higher in YOUNG in all measured force levels (Figure 1). The average age-related difference ranged between 3.5 and 25.4%, increasing to higher force levels. However, such an age difference was not seen in the dynamic contractions at the three measured force levels (10, 20 and 40% MVC; Figure 2).

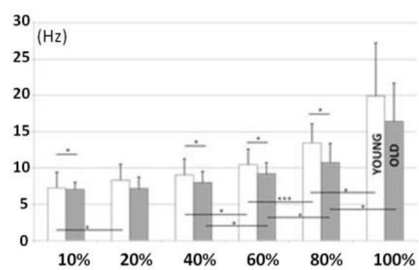

Figure 1: Motor unit discharge rate (1/s; X±SD) in YOUNG and OLD at different force levels in isometric contractions.

At the three lowest force levels all three contraction types were measured and showed that the MUDR was highest in concentric (CON) compared to isometric (ISO) or eccentric (ECC) in both age-groups (Figure 2). No significant differences in MUDR were found between ISO and ECC.

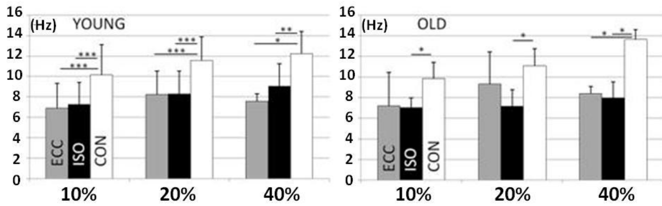

Figure 2: Motor unit discharge rate (1/s; X±SD) in YOUNG and OLD in eccentric (ECC), isometric (ISO) and concentric (CON) contractions at different force levels.

The relative global sEMG activities of SOL and GM, as measured by the surface electrode, were higher in OLD compared to YOUNG in all conditions and force levels despite the fact that the relative force levels did not differ between the age-groups. The age-related differences were largest in dynamic contractions, while statistically more significant differences were found in ISO.

DISCUSSION

In the isometric contractions the mean soleus MUDR was significantly lower in OLD in all measured force levels. The decreased MUDR has been suggested to be an adaptation to the increased twitch duration to optimize force generation [Kallio et al, 2012; Roos et al, 1997]. It has been shown that the soleus twitch duration increases with age, suggesting that tetanus can be achieved with lower discharge rates [Dalton et al, 2009; Dalton et al, 2010]. No clear differences in MUDR between age-groups were found in the dynamic contractions. However, the results generally confirmed earlier findings of larger MUDR in the CON compared to both ISO and ECC [Søgaard 1996]. Relative sEMG levels, especially in dynamic contractions, were higher in OLD than in YOUNG, which could explain the increased MUDR and thus reduce the group-difference. Higher muscle activation with similar MUDR would indicate a higher reliance on recruitment rather than rate coding in the elderly. Previous studies have found an age-related increase in coactivation during dynamic contractions like walking [Schmitz et al, 2009], which could also partly explain the observed difference in EMG/force relationship between the two groups. In ISO trials the differences in MUDR between YOUNG and OLD increased with increasing torque level. The more pronounced difference at high isometric forces could indicate that smaller differences should also be expected at the lower dynamic force levels.

CONCLUSION

It can be suggested that age-related differences in motor unit control do exist also in large leg muscles playing an important role in human locomotion and balance control. The lack of an age-difference in dynamic contractions could be due to differences in recruitment-strategies, coactivation or a lack of recording from high force levels.

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EFFECT OF BODY COMPOSITION ON STRENGTH OF UPPER AND LOWER EXTREMITIES IN SENIOR WOMEN

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INTRODUCTION

Aims of this study was to analyze the relationship between the selected body composition variables and strength of arms and legs in senior women. Age related changes in body composition (BC) and strength output have implications for physical function and health. A redistribution of fat and an increase in fat and a loss of muscle mass may result in a substantial decrease in the senior´s functional capacity. Although the BC, as well as age-related changes in it, has a strong genetic component, it is also significantly affected by environmental factors. The primary influences of BC are nutrition, disease, and mainly physical activity (Spirduso 1995). Clinically, the most used BC model describes the human body mass (BM) as a sum of the fat mass (FM) and the fat-free body mass (FFM) components (Blanchard et al.1990). In a majority of cases, this model could be accepted, but for more detailed characterizing of movement predispositions, it is better to use the 3-C molecular model that may be described in the following form (Heyward and Wagner 2004):

BM = FM + FFM = FM + ECS + ECF + BCM; FFM = ECS + ECF + BCM; FFM = ECM + BCM

ECS = extracellular solids, ECF = extracellular fluids, and BCM = body cell mass. The BCM is a sum of oxygen-using, calcium-rich, glucose-oxidising cells and is recognized as an indirect measure of the ability of a person to sustain mechanical work (Bunc et al. 2000). Because FFM is depends on BCM, this is often used to characterize the FFM and/or predisposition for muscle work the relationship ECM/BCM. Generally, it is well recognized that lower ECM/BCM value correspond to a better predispositions for muscle power output (Bunc et al. 2000).

Beginning in the middle of adulthood, FFM begins to decline gradually both in men and women, primarily due to the loss of muscle tissue (Blanchard et al. 1990). Similarly to FFM, the body cell mass (BCM) decreases with age in subjects without any systematical physical training, and thus significantly changes the predispositions for exercise. This similarity is confirmed by a highly significant positive correlation between these two variables that was found in senior women (Bunc et al. 2000).

METHODS

This study includes 58 healthy senior women whose mean age was 68.7±5.0 years, body mass=69.9±7.9 kg, body height=161.0±2.8 cm). The functional variables were assessed in open system with TEEM 2000M, and participants were loaded on an increased exercise (walking) on treadmill with inclination of 1.5%. The exercise was started on speed of walking 3 km.h^{-1} and was increased by each minute about 1 km.h^{-1} till subjective exhaustion. The strength of arms was assessed by handgrip and legs by number of up and down the steps (UDS). Each participant was asked to ascend and descend a flight of 35 cm steps as quickly as possible during a time of 30 s. The step ascent calculating began on the participant's first movement and concluded when the participant reached the top of the steps. Numerous tools and methodologies have been developed to measure BC parameters. The bioelectrical impedance analysis (BIA) seems to be one of the most used methods in field settings (Heyward and Wagner 2004). Regardless of which instrument is chosen to assess BC, the method is only as good as the measurement technique and prediction or conversion formula applied. To remain valid, the conversion formulas and prediction equations selected must be restricted to the populations from which they were derived (Bunc et al. 2000, Heyward and Wagner 2004).

RESULTS

BC and strength of extremities was assessed in a group of healthy senior women (n=53, age=68.7±5.0 years, BM=69.9±7.9 kg, height=161.0±2.8 cm, %BF=37.5±5.1 %, FFM=43.7±6.8 kg, ECM/BCM=0.98±0.03, VO_{2peak}.kg$_{1}$=25.9±4.3ml.kg$_{-1}$.min$_{-1}$, speed$_{peak}$=6.5±0.9 km.h$_{-1}$, handgrip absolute=25.3±2.1kg, handgrip relative=36.1±4.8, UDS=21.1±3.2 s$_{-1}$). We found a significant positive correlation between FFM and speed of treadmill walking ($p<0.05$), handgrip absolute ($p<0.01$), and UDS absolute ($p<0.05$), and UDS relative ($p<0.01$), and negative correlation between ECM/BCM and speed of treadmill walking ($p<0.005$), handgrip absolute ($p<0.005$), and UDS absolute ($p<0.01$), and UDS relative ($p<0.01$).

DISCUSSION

Muscle strength is significantly dependent on muscle mass that is necessary condition for realization of exercise. This is very important in seniors, where it should be the main reason of their dependency (Seguin and Nelson 2003). It is documented that the decline of muscle strength with age has been quantified as about 15% per decade after the age of 60 (Vandervoort and McComas 1986). From a limited research that has been done in elderly women, a positive relation seems to be between the activity level and muscle strength (e.g. Spirduso 1995).The reduced muscle mass with ageing is caused by (a) a reduction of the volume of individual fibres, (b) a reduction of the total number of fibres, (c) a combination of the two (Latham et al. 2004), and (d) alterations in the internal arrangement of muscle fibres, known as ‘‘muscle architecture’’. The decline in muscle mass alone does not account for the age-related decrease in maximal and explosive force production capacity. In addition, neural factors (Spirduso 1995) also contribute to impaired strength performance in old age. Physiological changes that are connected with ageing may by significantly influent by suitable exercise. This is necessary adapt to actual development state each subject (Faina et al. 2008, Jancey et al. 2008, Latham et al. 2004, Seguin and Nelson 2003, Spirduso 1995, Stewart et l. 2001). The factor that is most important for a physical independence of seniors is muscle strength (Spirduso 1995). The form of physical training (strength or endurance) plays a decisive role for the level of muscle mass, and thus of muscle strength. In older adults, previous studies investigating the influence of the acute program variables on muscle mass and strength development associated with exercise have largely examined the effect of training load. These studies indicate that low-intensity exercise (40% of 1-RM) is equally effective, or possibly more effective, than high-intensity resistance training (80% of 1-RM) for developing strength in older participants (Fahlman et al. 2011).

CONCLUSION

This study showed that body composition (FFM, ECM/BCM) is correlated to functional fitness in elderly women. Particularly, body composition is a factor that influences the reduction in muscle strength, flexibility, and endurance of the upper and lower extremities. This indicates that reduced quality of muscle mass has a negative effect on walking speed and functional fitness of facility-dwelling elderly women. In conclusion, body composition may be used like a criterion of strength upper and lower extremities and thus could be accepted like a criterion of women senior´s independency and self-serving.

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ORAL PRESENTATION 3

Friday Oct. 26th
11:30 – 13:30
(Auditorium A)

11:30 – 11:45
Atle Hole Saeterbakken
Correlation between core stability, core strength and core endurance

11:45 – 12:00
Akitoshi Sogabe
Quadriceps training proposal taking into account knee alignment

12:00 – 12:15
Roland Van den Tillaar
The effect of fatigue upon muscle patterning and performance in bench press

12:15 – 12:30
Thue Kvorning
Field tests and related reference values for optimization of physical conditioning of danish world class team-handball players

12:30 – 12:45
Kimitake Sato
Preliminary study: bilateral strength asymmetry characteristics of collegiate men's and women's soccer players

12:45 – 13:00
Jesper Sjökvist
Development of strength, power, and speed from 2001-2012 in women's national team football

13:00 – 13:15
Terje Gjøvaag
Hemodynamic responses to resistance training in patients with cardiac disease

13:15 – 13:30
Jani P Vaara
Associations of waist circumference, muscular and cardiorespiratory fitness with cardiovascular risk factors in young adult men

CORRELATION BETWEEN CORE STABILITY, CORE STRENGTH AND CORE ENDURANCE

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INTRODUCTION

Core training has been used in rehabilitation, injury prevention, enhance general health and performance among athletes (5, 9, 10). The core, or more specifically, the lumbopelvic region (3), connects the upper and lower extremities and is the anatomic centrepiece of the kinetic chain (2). Core training can be divided into core stability training, core strengthening training and core endurance training (5). Core stability is the ability to control the motion and position of the core to allow optimal production, transfer and control of force (6). Core endurance training is typically performed using low loads and long contraction times in isometric exercises (1) while core strength maximizes the transfer and generation of force in the core to the extremities (6, 9). In the literature, the term core training is used variously (5, 9). The training approaches have been examined and tested separately (4, 7). To our knowledge, however, the association between stability, strength and endurance of the core has not been reported. Therefore, the aim of the study was to examine the correlations between core stability, core strength and core endurance.

METHODS

26 males and 26 females (age 22.1 ± 2.3 years, stature 1.74 ± 0.06 m, body mass 70.8 ± 7.5 kg) were recruited for this study. All subjects were tested in isometric core strength, core endurance and core stability in randomized order. The core strength test was tested three times in 3 seconds with maximal voluntary contraction using a modified Bergström-Sörensen test (7) in the median plane (back and abdominal) and coronal plan supine on a bench (figure 1). A force cell (Ergotest Technology AS, Langesund, Norway) was attached to the trunk to measure the maximal force in the core muscles. The core endurance test was identical to the core strength test, but the aim of the test was to maintain the position as long as possible. The core stability test was conducted on a force platform (Ergotest Technology AS, Langesund, Norway) measuring the postural sway (4). After 25 familiarization tests, the subjects stood on one knee with the arms crossed to isolate the core. The test was conducted 5 times on both legs in 10 seconds. The best attempt was used in further analyses. Pearson's r was used to examine correlations between the variables. A correlation of 0.2 was considering small, 0.5 medium and 0.8 large. Statistical significance was accepted at $P \leq 0.05$

Figure 1: The testing position of the core strength, endurance and stability.

RESULTS

Table 1. The correlation between core strength, endurance and stability. * Indicates a significant correlation between these two parameters on a $p \leq 0.05$ level.

Tests	Strength abdom.	Strength back	Strength side	Endur. abdom.	Endur. back	Endur Side	Stability pref. leg	Stability non-pref. leg
Strength abdominal		0.51*	0.69*	0.02	-0.07	0.15	0.07	0.06
Strength back	0.51*		0.72*	0.04	-0.12	0.31*	-0.04	0.20
Strength side	0.69*	0.72*		-0.06	-0.03	0.44*	-0.01	0.22
Endurance abdominal	0.02	0.04	-0.06		0.07	0.01	0.08	0.03
Endurance back	-0.07	-0.12	-0.03	0.07		0.55*	0.16	0.02
Endurance side	0.15	0.31*	0.44*	0.01	0.55*		0.23	0.29*
Stability preferred leg	0.07	-0.04	-0.01	0.08	0.16	0.23		0.61*
Stability non-preferred leg	0.06	0.20	0.22	0.03	0.02	0.29*	0.61*	

Correlations between core strength, endurance and stability in the abdominal, back and side were varying between r = -0.12 and 0.44 (p = 0.002-0.96). Only endurance side was significantly correlated to strength (back and side; p = 0.025-0.001), endurance back ($p \leq 0.001$) and stability in non-preferred leg (p = 0.04). A significant correlation was observed between different strength parameters (abdominal, back and side; $p \leq$ 0.001) and between the two stability parameters (preferred and non-preferred; $p \leq 0.001$).

DISCUSSION

Based on the present results, the correlation between the variables was considered non-existing to medium. Not surprisingly, stability of the core seems to be relatively independent of the leg since the core was isolated in the testing procedure. Further, the ability to generate force in one muscle group is correlated with the ability to generate force in another muscle group. Endurance side is the variable that correlates with several other variables. However, the oblique muscles are an imported contributor to force generation and stability in unilateral movements (8). Due to the large number of comparisons, the few positive correlations could also be caused by type II errors. The results are supported by previous research (4) They reported no significant correlation between postural control (static and dynamic) and strength/power of the lower extremities (4). Based on the results of the present study, different neuromuscular mechanisms appear to be responsible for regulating the different variables in core training. The different training approaches (strength, endurance and stability) therefore need to be addressed separately or integrated (8, 9).

CONCLUSION

Core stability, core strength and core stability appear to be relatively unrelated in a sample of healthy young males and females. Hence, when designing a training program for the core muscles, one must use training approaches that are specific to the aim of the training.

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QUADRICEPS TRAINING PROPOSAL TAKING INTO ACCOUNT KNEE ALIGNMENT

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INTRODUCTION

Lower limb muscle training is commonly undertaken for rehabilitation and to improve sport performance and reduce the chance of injury. The quadriceps femoris, a knee extensor muscle, plays the most important role in leg muscle training and functions to stabilize the patella, as well as to flex the knee joint[1). Imbalance between the vastus medialis (VM), which pulls the patella inward, and the vastus lateralis (VL), which pulls the patella outward, may cause patellofemoral pain syndrome (PFPS) [2].

Many attempts have been made to develop a method for individually stimulating each quadriceps muscle, but none have been successful. An investigation of the component ratio of each quadriceps muscle by cross-sectional magnetic resonance imaging (MRI) in subjects with differing knee alignment (normal, genu varum, and genu valgum) revealed that the VM is hypertrophied compared with the VL in genu varum whereas the VL is hypertrophied compared with the VM in genu valgum [3]. In other words, even if the same training program is implemented, the load arising at the VM and VL might differ due to individual knee alignment differences. Thus, quadriceps training that does not take into account knee alignment might cause an anomalous load on each quadriceps muscles due to differences in knee characteristics, and training performed for strengthening and rehabilitation could instead cause an imbalance of the VM and VL, spurring knee pain.

The objective of this study was to calculate the VM/VL ratio by measuring the EMG of the VM and VL during knee extensions (OKC) and leg presses (CKC) in subjects with different knee alignments, thus elucidating whether or not the muscle activity balance of the VM and VL differs according to different knee alignment.

METHODS

Subjects were 18 healthy men: 6 with normal knees, 6 with genu varum, and 6 with genu valgum. Knee alignment of each subject had been classified based on (a) distance between the medial condyles of the knee, (b) distance between the calcanei, and (c) the femorotibial angle (FTA). The FTA was confirmed on conventional anteroposterior X-rays of the left knee.

Studies on Japanese subjects have reported an average FTA of 176–178°, and by taking (a), (b), and (c) into account, genu valgum was defined as ≥3 cm between the calcanei with an FTA <173°, a normal knee as having an FTA between 173° and 178°, and genu varum as ≥3 cm between the calcanei with an FTA ≥178°.

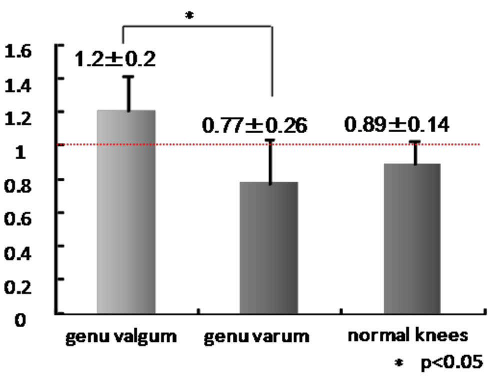
Using an isokinetic muscle contraction exercise device (BIODEX,NY), each subject performed knee extension exercises (60°/s, 180°/s, and 300°/s), during which time the level of muscle activity of the VM and the VL was determined by electromyography (Telemyo 2400,Noraxon, AZ). Furthermore, each subject performed three leg press repetitions using a load of 75%/one rep max. The speed of the motion was indicated at 60 beats/min using an electronic metronome, and one 2-s motion comprised a 1-s flexion phase and a 1-s extension phase. Electromyography of the VM and VL was measured during the extension phase.

The VM/VL ratio was determined by dividing the level of VM activity by the level of VL activity, and the balance between VM and VL muscle activity was then compared between the three groups. The VM/VL ratios in each group were compared using the nonparametric Kruskal-Wallis test because data showed non-normal distribution. Significant differences were followed by multiple comparison testing. Significance was set at 0.05.

RESULTS

The VM/VL ratio at each speed during knee extension was as follows. At 60°/s: 0.89±0.14 for normal knees, 0.77±0.26 for genu varum, and 1.2±0.2 for genu valgum; at 180°/s: 1.03±0.27 for normal knees, 0.83±0.24 for genu varum, and 1.25±0.27 for genu valgum; and at 300°/s: 0.87±0.28 for normal knees, 0.85±0.29 for genu varum, and 1.25±0.44 for genu valgum. There was a significant difference

(p=0.02) between genu varum and genu valgum at 60°/s, but no other significant differences were noted at the other angular velocities (Fig. 1).
The VM/VL ratio during the knee extension phase of the leg press was 1.02±0.14 for normal knees, 1.24±0.21 for genu varum, and 0.86±0.13 for genu valgum ($p<0.05$) (Fig. 2).



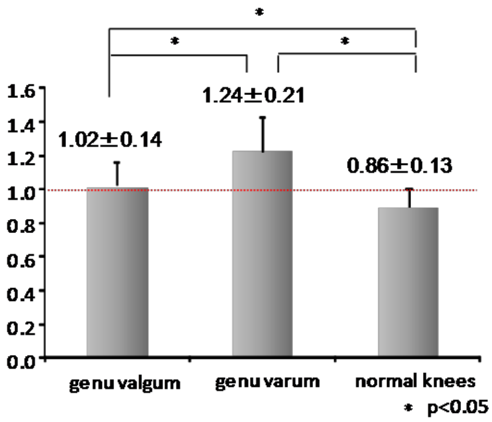


Fig. 1 VM/VL ratio during knee extension (60°/s) Fig. 2 VM/VL ratio during leg press

DISCUSSION

Results revealed that for knee extensions (OKC) at maximum contraction at low speeds, the VM is more active than the VL in the genu valgum group, whereas the VL is more active than the VM in the genu varum group. For leg press (CKC), the VM is more active than the VL in the genu varum group, whereas the VL is more active than the VM in the genu valgum group. Sogabe et al. (2009) investigated the cross-sectional area of each quadriceps muscle by MRI and reported that the VM cross-sectional area was greater than the VL area in the genu varum group and that the VL area was greater than the VM area in the genu valgum group; this is equivalent to the result of the VM/VL ratio of muscle activity during training[3]. However, the VM/VL ratio during knee extension was opposite.
The human knee joint is constantly exposed to a load, so it can be considered that the with respect to longitudinal load (CKC), the VM is active, which increases the VM cross-sectional area in genu varum, while the VL is active on a daily basis in genu valgum. However, in motions such as OKC, it is likely that the VL is more active in genu varum, whereas the VM is more active in genu valgum; the probability of both muscles being strongly activated in response to a load on an everyday basis is low. Consequently, when knee alignment differs, even if the same training is performed for stimulating the quadriceps, the stimulation of the VM differs from that of the VL. Thus, if subjects with malalignment continue only CKC training, such as squats and leg press, further VM/VL imbalance will likely be promoted, with the possibility of spurring knee pain such as PFPS.

CONCLUSION

This study revealed that VM and VL activity differs by training method (OKC and CKC) for stimulating the quadriceps as a result of differences in knee alignment. Thus, an abnormality in knee alignment might spur knee pain because of a VM/VL imbalance if a uniform method of training is implemented. Consequently, it would be ideal to adopt a program of both OKC and CKC training for strengthening the quadriceps muscle.

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THE EFFECT OF FATIGUE UPON MUSCLE PATTERNING AND PERFORMANCE IN BENCH PRESS?

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INTRODUCTION

In strength training for different sports, bench press is one of the most popular exercises for the upper body. In training athletes perform several sets at sub-maximal loads with several repetitions at a certain percentage of 1-RM to exhaustion. During these sets, fatigue is often experienced and sometimes the last repetition has to be done with some help. This fatigue is recognized as a multifactorial phenomenon often shown in loss of force production and thereby visible as a loss of peak barbell velocity in bench press (Sánchez-Medina & González-Badillo2011; Drinkwater et al., 2007). Several studies are limited by only investigated the loss of power, force and velocity output during sets with sub-maximal loads (Sánchez-Medina & González-Badillo 2011; Duffey & Challis, 2007). However, litle is known about the muscle patterning during these sets. In the literature, conflicting results were found in which some studies showed increased muscle activation during fatigue in resistance training (Gentil et al. 2007; Bennecke et al. 2009), while others showed a decreased EMG following maximal strength loading (Häkkinen, 1993). Walker et al. (2012) showed in leg press that in maximal strength training (15 sets of 1-RM) EMG decreased while with hypertrophic training (15 sets of 10-RM) EMG amplitude increased. Gentil et al. (2007) and Bennecke et al. (2009) showed in bench press that some muscles had similar EMG amplitude, while others increased in activation during fatigue. However, they used a pre-exhaustion exercise to investigate the effect of fatigue and not what happened acute during one set of bench press lifting. Therefore the aim of this study was to examine the effect of fatigue during 6-RM bench pressing upon the muscle patterning and performance. We expected an increased EMG amplitude of the prime movers as found by Walker et al. (2012) in leg press.

METHODS

Fourteen healthy, resistance-trained males (age 22.5 ± 2.0 years, stature 1.82 ± 6.6 m, body mass 82.0 ± 7.8 kg) with around 4.6 ± 2.1 years of resistance training experience participated in this study. All subjects were familiar with the bench press exercise. 6-RM was tested after a habituation session to identify 6-RM in two weeks prior to the experimental test. EMG (Musclelab 4020e) was measured of the triceps brachii, the anterior deltoid, the sternal portion of the pectoralis major and the biceps brachi. A linear encoder (ET-Enc-02, Ergotest Technology AS, Langesund, Norway) was syncronized with the EMG recordings and attached to the barbell measured the lifting times, velocity and vertical position of the barbell, so that the start, lowest barbell position and end of repetition (Rep) 1, 3 and 6 could be identified. These repetitions were compared with each other in two phases (eccentric and concentric) to identify differences in kinematics and muscle patterning between the three repetitions. Statistical significance was accepted at $p \leq 0.05$.

RESULTS

The 6-RM strength was 85 ± 15.6 kg. The average and peak velocities decreased significantly from Rep 1 to 6 in the concentric phase, while in the eccentric phase the velocity was only lower in Rep 1 compared to the other two (table 1). Furthermore, the eccentric phase was significantly longer in Rep 1, while the concentric phase period increased from Rep 1 to 6. This resulted in a significantly longer total time for Rep 6 compared with the other two (Table 1).

Table 1. Kinematics of repetition (Rep) 1, 3 and 6 during eccentric (ecc) and concentric (conc) phase in 6-RM.

	Average velocity (m/s)		Peak velocity (m/s)		Time (s)		
Variable	v_{ecc}	v_{conc}^{b}	v_{ecc}	v_{conc}^{b}	t_{ecc}	t_{conc}^{b}	t_{total}
Rep 1	.29±.08[a]	.33±.03	.47±.13[a]	.49±.06	1.32±.44[a]	1.16±.11	2.48±.0.51
Rep 3	.42±.11	.28±.04	.63±.16	.44±.08	.92±.21	1.36±.19	2.28±.0.30
Rep 6	.36±.13	.14±.06	.56±.17	.35±.09	1.07±.34	3.11±1.81	4.18±1.98[a]

[a] indicates a significant difference between this rep and the other two at p<0.05.

[b] indicates a significant difference between all three reps at p<0.05.

In the eccentric phase the mean muscle activity (RMS) increased significantly for the pectoralis and deltoid muscles from Rep 1 to 3, while for the triceps and biceps muscles no significant differences were found in this phase (Fig. 1). In the concentric phase the deltoid and pectoralis muscles increased activity significantly from Rep 1, 3 to 6, while for the triceps only a significant increase was found in Rep 6 compared to the others. No significant differences were found for the biceps the concentric phase either (Fig. 1).

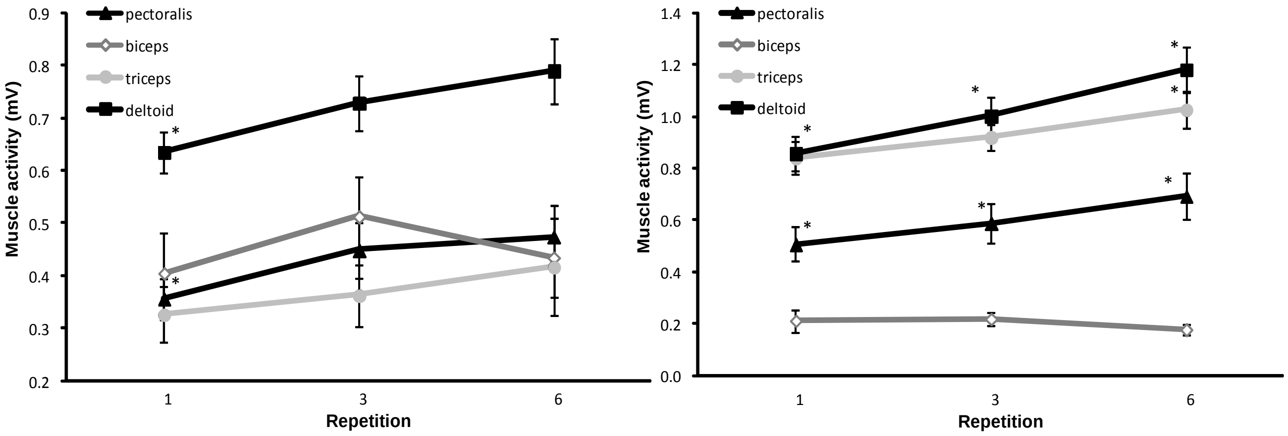

Fig 1. Mean (± SEM) muscle activity of the different muscles during the eccentric (left) and concentric phase (right) of attempt 1, 3 and 6 during the 6-RM. * significant difference in muscle activity from the other Reps at $p<0.05$.

DISCUSSION

As expected, decreased velocity of the barbell (Medina, 2011) and increased lifting time (Duffey & Challis, 2007) in the concentric phase during the 6-RM occurred, indicating that fatigue happened. However, in the eccentric phase the opposite was found: increased velocity and decreased lowering time probably caused by decreased movement control.

The EMG amplitude increased for the prime movers during the concentric phase as hypothesized (Fig. 1). However, only a significant increase for the triceps was found in Rep 6 and no significant difference in the eccentric phase indicated that not every muscle increases their neural drive. This was just the opposite of what Gentil et al. (2007) and Bennecke et al. (2009) found. They found similar EMG amplitude in the pectoralis and deltoid muscles, while an increase was found in the triceps during fatigue. These differences in findings were probably the caused by the protocol used. In our study we only performed one set of 6-RM and showed an increased EMG amplitude at Rep 6 for all prime movers. When performing several sets of 6-RM probably EMG amplitude increases already significantly after fewer Reps as indicated by Walker et al (2012). The biceps muscle; a stabilising muscle was not influenced much during the 6-RM indicating that fatigue only affected the prime movers in bench press. The present study was limited by only divided the bench press in two phases which did not give detailed information about the activation pattern of the selected muscles during the whole bench press exercise.

CONCLUSION

Our results obtained from surface EMG data may give some information about muscle activation strategies and consequences of acute neuromuscular fatigue during typical bench press loading. Our study indicates that by decreasing performance (lower barbell velocities) the EMG amplitude increases of the prime movers and that the antagonist muscle (biceps) activity is not affected by fatigue during 6-RM bench pressing.

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FIELD TESTS AND RELATED REFERENCE VALUES FOR OPTIMIZATION OF PHYSICAL CONDITIONING OF DANISH WORLD CLASS TEAM-HANDBALL PLAYERS

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INTRODUCTION

Currently the Danish women's and men's national junior and senior handball teams are collectively ranked as number one in the world by the European Handball Federation. Physical testing indicates that heavy, strong players, who are not compromised in regard to aerobic power or speed and agility seem to be superior (i.e. higher ranked) (Team Danmark, unpublished data). Consequently, the aim of this study was to find relevant field tests and to establish reference values for Danish national female and male handball teams at different ages for the purpose of optimizing physical conditioning. The requirements for the test-battery were that it must identify relevant physical skills in team-handball (i.e. speed, agility, strength and aerobic power). But at the same time, it had to be easy to use (e.g. players could test themselves), and it also had to be possible to test 20 players in less than 3 hours, with no need for high tech testing equipment. The test data also had to be easy to interpret and translate in to practical training guidelines. Furthermore, performing the tests had to be as equal to a physical conditioning session as possible, thus whenever team-handball players test themself they also perform relevant physical conditioning for team-handball. On the basis of the field tests it should then be possible to categorize team-handball players into different performance levels for the purpose of identifying unsatisfactory or satisfactory physical conditioning levels.

METHODS

With regards to the above mentioned requirements, a field testing battery (*Physprofile-tests)* was created. To test speed and agility specific for team-handball an agility test was made (handball agility (HA)), see figure 1. Relevant muscle strength (upper and lower body and core strength) was tested by 5 Repetition Maximum (RM) test in bench press and squat (thigh parallel to the floor) and by full hip flexion from vertical hanging by the knees (brutal crunches (BC), maximum repetitions performed). Finally, aerobic power was tested by 3000 m running time. In 2010 the women's senior team (WS) (n=23), under 18 team (U18) (n=16) and under 16 team (U16) (n=23) performed the *Physprofile-tests* and in 2011 the men's senior team (MS) (n=15), under 20 team (U20) (n=16) and under 18 (U18) (n=16) were tested. Test data were sampled for the different teams and mean and SD was used in constructing four groups of performance levels (i.e. *Physprofiles* (reference values)). Hence, on the basis of the Gaussian distribution 1 SD defined the margins between *Below average* and *Unsatisfactory* and between *Over average* and *Elite* (see table 2). Statistics; One-way Anova and Tukey's post-hocs, data are mean ± SD, p <0.05.

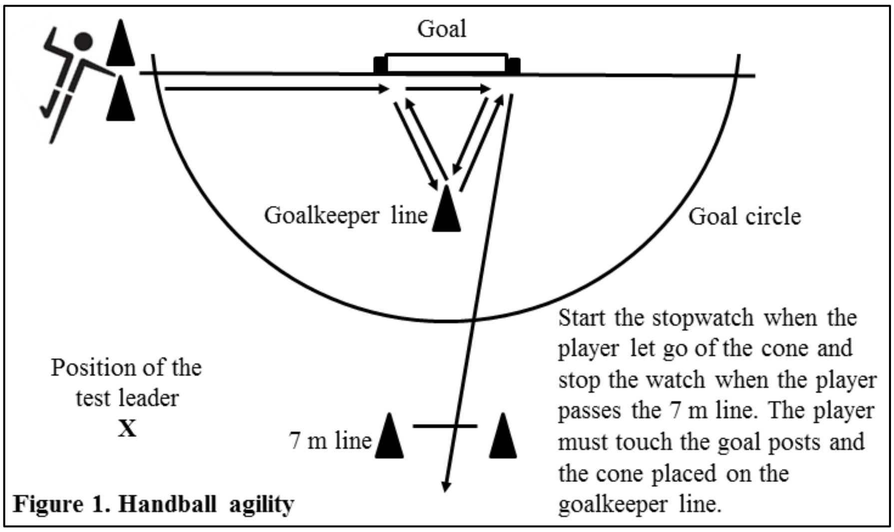

Figure 1. Handball agility

RESULTS AND DISCUSSION

Table 1 show the results obtained from the *Physprofile-tests*. The WS, U18 and U16 teams showed no differences in 3000 m and HA test. This was the same for the men, however, the U20 team was faster than the MS and U18 teams in the HA test. Unfortunately, some of the best physically conditioned players from the MS team were injured on the day of testing and to our best knowledge it has very likely affected the results obtained in the HA test, 5 RM squat and bench press and the BC tests. We would have expected better scores in these tests for the MS team and thus obtaining similar results as seen in the women's teams, hence the MS team possessing larger muscle strength than their younger counterparts and equal performance in the HA test, or else the MS and U20 teams being equally fast, but faster than the U18 team.

Table 1. *Physprofiles-test* results for female and male handball teams

Physprofiles-test	Women			Men		
	WS	**U18**	**U16**	**MS**	**U20**	**U18**
3000 m (min)	13.5 ± 1.0	13.1 ± 0.7	13.6 ± 1.2	12.56±0.32	11.31±0.56	11.12±0.17
Handball agility (s)	8.66 ± 0.33	8.73 ± 0.28	8.75 ± 0.30	7.98±0.17	7.64±0.25*	7.92±0.22
5 RM Squat (kg)	100.0±16.2*	65.0±6.4	60.7±8.7	132±18	130±35	118±21
5 RM Bench press (kg)	52.3±5.4*	48.5±4.2	41.2±5.4	95±14	94±18	80±8[#]
Brutal crunches (rep.)	18.9±5.9[#]	16.6±8.2	13.9±6.5	20±4[¤]	21±5[§]	17±5

***Women:** WS > U18 and U16, **Men:** U20<U18 and MS; [#] **Women:** WS > U16, **Men:** U18<U20 and MS
[§] **Men:** U20>U18, ([¤] MS > U18 (trend, p=0.08))

Table 2 shows the constructed *Physprofiles* (reference values) for female and male teams. 3000 m and HA is the same for all three national teams in both genders while the strength tests give different values for the three national teams. No subdivision in 3000 m and HA values was used whereas having subdivisions in the strength tests reference values was chosen on the basis of the results obtained and an general assessment of these results with regard to the overall requirements of the test-battery (see introduction). But also with respect to the fact that the WS and MS has larger body weight (Team Danmark, unpublished data) which may counteract aerobic power and agility but favors larger muscle strength explained by larger muscle mass but also by more strength training years, and finally with regard to the fact that some of the best conditioned MS players were injured on the day of testing. Finally, the reference values were further modified (i.e. levels increased) in relation to national coaches' expectations to future physical performance requirements.

Table 2. Women's and men's *Physprofiles* (reference values).

Physprofile-tests	**Teams**		***Physprofiles* (reference values)**							
			Unsatisfactory		**Below average**		**Over average**		**Elite**	
	Women	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
3000 m (min)	All	All	>14.21	>12.27	14.21 - 13.17	12.27 - 11.31	13.16 - 12.11	11.30 - 10.37	<12.11	<10.37
Handball agility (s)	All	All	>8.86	>8.14	8.86 - 8.57	8.14 - 7.92	8.56 - 8.26	7.91 - 7.70	<8.26	<7.70
Squat (kg)	U16	U18	<60	<97.5	60 - 70	97.5 - 117.5	71 - 80	120 - 140	>80	>140
	U18	U20	<72.5	<100	72.5 - 85	100 - 130	86 - 97.5	132.5 - 160	>97.5	>160
	Senior	Senior	<92.5	<122.5	92.5 - 107.5	122.5 - 140	108 - 122.5	142.5 - 162.5	>122.5	>162.5
Bench press (kg)	U16	U18	<37.5	<72.5	37.5 - 42.5	72.5 - 80	43 - 47.5	82.5 - 87.5	>47.5	>87.5
	U18	U20	<47.5	<75	47.5 - 52.5	75 - 92.5	53 - 57.5	95 - 102.5	>57.5	>102.5
	Senior	Senior	<52.5	<87.5	52.5 - 57.5	87.5 - 102.5	58 - 62.5	105 - 115	>62.5	>115
Brutal crunches (rep.)	U16	U18	<10	<12	10 - 17	12 - 17	18 - 24	18 - 22	>24	>22
	U18	U20	<13	<16	13 - 21	16 - 21	22 - 30	22 - 26	>30	>26
	Senior	Senior	<16	<18	16 - 22	18 - 22	23 - 29	23 - 26	>29	>26

CONCLUSIONS

In top level team-handball physical conditioning is a major part of the training and therefore performance testing in relation to relevant reference values is important to insure that physical conditioning translates in to sport specific and sufficient physical performance levels.

PRELIMINARY STUDY: BILATERAL STRENGTH ASYMMETRY CHARACTERISTICS OF COLLEGIATE MEN'S AND WOMEN'S SOCCER PLAYERS

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INTRODUCTION

Bilateral strength asymmetry (BSA) is often tested in performance-based research [2-4]. The definition of bilateral asymmetry that was stated in a previous study described as "kinetic and kinematic outcome difference between left and right sides of the body" [7]. There are several factors leading to the development of BSA such as limb dominance or previous injuries [1-4].

Soccer players must possess a combination of endurance and anaerobic capabilities in order to cover multi-directional distances on the field as well as adequate soccer skills to be competitive. More specifically, soccer players need to engage in several agility-related movement patterns such as rapid acceleration and deceleration as well as the ability to change direction quickly. In addition to those physical demands, they need to be strong for potential contact with opponents. Unlike one-side dominant sport skills such as throwing and striking, soccer players need to be capable of utilizing both sides of the body. Speculation suggests that being symmetrical in strength is a vital part of success for players. While BSA has been tested on specific athletes such as distance runners [7], there is also a need for testing agility athletes.

Therefore, the purpose of the study was to analyze symmetry index (SI) scores of force exertion variables from isometric mid-thigh pull strength tests on collegiate soccer players. The study compared the SI scores between male and female soccer players for sex differences. Excluding goal keepers, movement patterns appear to be similar among all positions. Thus it was hypothesized that a small range of SI scores would be observed, also based on previous findings, that female soccer players would produce higher SI scores [1].

METHODS

Volunteers were competitive collegiate soccer players (*N*=78). Both male (*n*=43) and female players (*n*=35) reported to sport science laboratory for a series of athlete monitoring tests. The isometric mid-thigh pull is a part of an ongoing monitoring program that examines strength and power by pulling an immovable bar in a custom designed squat rack. All subjects ranged from age 18 to 23, and had at least one year collegiate athletic experience, and up to four years. The test was in accordance with the University Institutional Review Board.

Force variables were measured on 45.5 cm x 91 cm force platforms affixed side by side (Rice Lake, WI) sampling at 1,000 Hz. The apparatus and standard joint angles were established based on a previous study [5]. Immovable bar heights were set to previously measured distances specific to the individual, with a knee angle of 125º ± 5º and hip angle of 175º ± 5º. Subjects' hands were attached to the bar using straps and athletic tape to prevent hand movement and to ensure maximum efforts could be given for each pull without the limitation of hand grip [5]. Warm-up protocol for all subjects consisted of the following in the same order: thirty jumping-jacks, one set of five of dynamic pulls from mid-thigh position with 20 kg, and two sets of five at 60 kg (40 kg for female subjects). Then subjects participated in practice isometric pulls at submaximal intensities at 50 and 75% effort level. As subjects stood on the bilateral force platforms, they were positioned at the center line of the two platforms. Two maximal effort trials were completed lasting 3-4 sec., with two minutes rest between the trials. During each maximal trial, subjects were instructed to "pull as hard and as fast as possible."

The trials were processed to calculate peak force and force exerted at 250 ms from each side using LabView software (National Instruments Co., Austin, TX). SI score was calculated using an equation from a previous study [6]. The groups' SI score average for each force variable was calculated and used Independent T-test for gender comparison. An α level was set to 0.05. PASW software was used for the analyses (SPSS version 19: An IBM company, New York, NY).

RESULTS

Descriptive data showed both forces' SI scores were relatively the same in average and range for a total of seventy-five subjects (in Table 1). The results also showed that there were no statistical differences on both force variables between male and female players (peak force: $T(1,76) = -2.02$, $p = 0.05$; force @ 250 ms: $T(1,76) = -1.54$, $p = 0.13$).

Table 1
Descriptive data of Symmetry Index (SI) scores in percentage (%)

	M Soccer (n=43)	W Soccer (n=35)	Total (n=78)	Min – Max (n=78)
Peak force SI score	4.87 ± 2.73	6.57 ± 4.66	5.64 ± 3.93	0.16 - 17.09
Force at 250 ms SI score	4.93 ± 3.93	6.39 ± 4.45	5.58 ± 4.21	0.05 - 17.07

DISCUSSION

The study hypothesis was not supported by showing non-statistical significance comparing male and female SI scores on two force variables. By further analyzing the data, it is obvious that both force variables displayed fairly large coefficient of variations ranging from 56 to 80% in each gender. At the same time, both SI scores were a range of 17%. Although there is no study indicating a threshold to determine whether the SI score has practical significance, the current data showed an interesting result. By qualitatively assessing the data, players displaying SI scores of over 10% in peak force indicate sex differences; only one male player as compared to nine female players. For the force at 250 ms, four male players and eight female players displayed over 10 % of the SI score. Although no category of "good" and "bad" SI scores has been established, there is a need for categorically grouping of "low", "moderate", "high", and "extreme" SI scores. In order to better evaluate SI scores, categorical variables need to be established to assess BSA on athletic populations.

Soccer is a contact-sport with injuries occurring due to physical contact, but non-contact injuries are also common. There is also evidence that non-contact injuries are more prevalent among female athletes. Review of the literature suggests the higher female non-contact injury rate could be due to several factors such as overall athleticism, anatomical structures, and overall or specific points of body strength [1]. With current data, it is not clear that high SI scores can be a factor to predict potential non-contact injuries. Future studies are needed to analyze the relationship between incidence of injury and SI scores.

CONCLUSION

The study results showed that the SI scores of force variables vary ranging from 0 to 17%. There was no statistical difference between male and female soccer players. Further analysis of BSA still seems important for both the performance perspective as well as the potential for non-contact injury prevention.

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DEVELOPMENT OF STRENGTH, POWER, AND SPEED FROM 2001-2012 IN WOMEN'S NATIONAL TEAM FOOTBALL

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INTRODUCTION

The Swedish Football Federation in cooperation with the Swedish Olympic Committee have performed strength and power assessments of the senior women's national football team since 2001 to current date. The assessments are a part of an assessment package known as "Fysprofilen" developed in the late 1990's. It is commonly accepted that the women's game have followed the men's game with an increase demand in physical power and speed (Stolen et al. 2005). The purpose of this study was to describe and analyze the development of strength, power, and speed in Swedish female national team players from 2001-2012.

METHODS

The data was collected at the same time period each year, between February 20th -1st March, for the years 2001-2005 and 2007-2012. For each year, a group of 11 players (including one goalkeeper) participating in the respective year's major tournament was selected for analysis of upper and lower body maximal and relative strength, power, and speed. Upper and lower body maximal strength was assessed using a 1repetition maximum (1-RM) bench press and parallel back squat while relative strength was assessed as a % of kg lifted in relation to body weight. Power was analyzed using a squat jump (SQJ), countermovement jump (CMJ), and a countermovement with arms (CMJa) while speed was analyzed using a 10m, 20m, and 30m sprint run (Maulder & Cronin, 2005). The jumps were measured using a hop mat and speed using timing gates (IVAR, SH Sport & Fitness, Mora, Sweden). Repeated measures ANOVA was used to detect any significant differences in maximal and relative strength, power, and speed from 2001 - 2012.

RESULTS

Over an 11 year period, the average height and weight were 170.4 ± 4.7 cm and 65.0 ± 6.0 kg (n = 210), bench press 1-RM 50.1 ± 7.7 kg or 77.4 ± 9.4% of body weight (n = 185) , parallel back squat 1-RM 84.4 ± 15.2kgor130.1±21.2%ofbodyweight(n=202) ,SQJ29.2±3.2cm(n=220),CMJ31.3±3.3cm(n= 220), CMJa 36.5 ± 3.9 cm (n = 220), 10 m sprint 1.81 ± 0.06 s (n = 195), 20 m sprint 3.19 ± 0.10 s (n = 195), and 30 m sprint 4.50 ± 0.15 s (n = 195). When comparing 11 players participating in the major tournament from each year, there was no difference in player height or weight over 11 years of testing. The 2003 players had a significantly higher maximal lower body strength ($p < 0.001$) while in both 2003 and 2004 relative lower body strength was significantly higher ($p<0.001$ and $p < 0.03$, respectively) than any other year between 2001 and 2012. Only in 2004 was upper body relative strength significantly different ($p < 0.004$). Power was only significantly different in 2012 when comparing SQJ and CMJ ($p < 0.02$ and $p < 0.03$, respectively) to all other years. Speed has remained unchanged over the 11 year period.

DISCUSSION

The Swedish national team women's players have not significantly developed maximal or relative strength, power, or speed significantly from 2001-2012. Since the introduction of the women's FIFA world ranking in 2003, Sweden have remained a top-5 nation in women's football which may suggest that other qualities such as technique, skill, and game awareness has improved, allowing for a lack of development in physical qualities (FIFA.org).

CONCLUSIONS

Though it's commonly accepted in women's national team football that the speed of the game and the demand of power and explosive movements have increased over the last 10-15 years, there is little to suggest that an increase in strength, power, and speed as measured by these methods should provide an advantage on the football pitch.

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HEMODYNAMIC RESPONSES TO RESISTANCE TRAINING IN PATIENTS WITH CARDIAC DISEASE

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INTRODUCTION

People with cardiac disease have low cardiorespiratory fitness and generally suffer from muscle atrophy and impaired muscle strength. Consequently, these patients are in great need of effective resistance training (RT) programs. Recent guidelines (e.g. Williams et al., 2007) recommend RT with moderate intensity (40-60 % of one repetition maximum; 1RM) for cardiac patients. Cardiac patients, however, often perform RT with much higher loading (e.g. 90 % of 1RM; Karlsen et al., 2009), but the hemodynamic responses of cardiac patients to heavy RT is little investigated. The purpose of the study was to compare the hemodynamic responses of cardiac patients following moderate intensity RT (40-60 % 1RM, i.e. international recommendations) and following heavy RT (~90 % 1RM).

METHODS

Subjects: Eleven male and four female patients with a previous history of coronary artery disease, angina pectoris or infarction, participated in this study. Their mean (SD) age weight, height and BMI was: 62.4 (7.3) yrs., 79.9 (13.8) kg, 176 (11.7) cm and 25.4 (2.0) kg m2. *Experimental design:* The patients performed two sessions of sitting leg-extensions without breath holding (Valsalva maneuver).The sessions were separated by 48 hours. The load during the RT was 3 series (S) of 15RM, (55 % of 1RM), or 3 series of 4RM (86 % of 1RM). The sessions were performed in a randomized order. *Measurements:* Beat-for-beat systolic (S) and diastolic (D) blood pressure (BP) was monitored by a Finometer Pro (Finapres Medical Systems). Lactate (Arkay Lactate Pro) and ratings of perceived exertion (RPE; scale 6-20) was measured at rest and immediately following three series of RT.

RESULTS

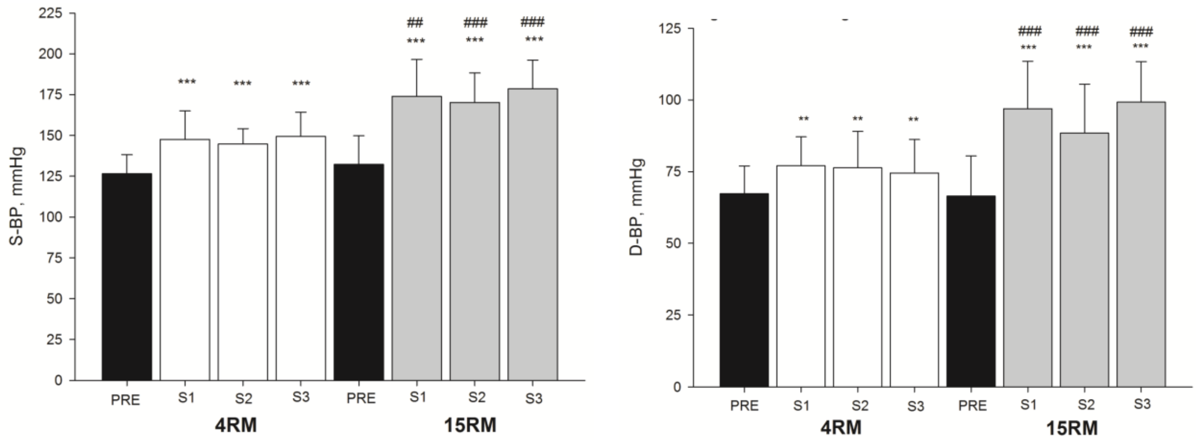

Fig 1 A and B. Systolic and diastolic blood pressure following strength training

A). Pre S-BP vs. S-BP following Series (S) 1, 2 and 3 (S1, S2, S3); ***p < 0.001. 4RM S-BP following S1, S2, S3 vs. 15 RM S-BP following S1, S2, S3; ### p < 0 .001. **B)**. Pre D-BP vs. D-BP following S1, S2, S3; ***p < 0.001, **p < 0.01. 4RM D-BP following S1, S2, S3 vs. 15 RM D-BP following S1, S2, S3; ### p < 0 .001.

Lactate and ratings of perceived exertion (RPE). Mean (SD) Pre 4RM and 15RM LA values were 1.2 (0.3) and 1.3(0.3) Mmol/L, respectively. Following RT, Post 4RM and 15RM LA values were 2.5(1.2) and 6.6(1.9) Mmol/L, respectively (p < 0.001). Mean (SD) Pre 4RM and 15RM RPE scores was

6.2(0.5) and 6.1(0.3), respectively, while following RT, Post 4RM and 15 RM scores were 12.7 (1.4) and 15.5 (1.7), $p < 0.001$.

DISCUSSION

When cardiac patients perform RT following international recommendations, the S-BP and D-BP response is about 20 % higher compared to the BP response following 4RM RT. In addition, lactate levels and RPE scorings are significantly lower following 4RM RT. Thus, cardiac patients may tolerate heavy RT better than RT with moderate loadings when the RT is performed without breathholding.

The BP response is probably more related to the duration of each work period than the actual weight lifted.

CONCLUSION

There is a need to evaluate and possibly review international guidelines for RT of cardiac patients and elderly people.

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ASSOCIATIONS OF WAIST CIRCUMFERENCE, MUSCULAR AND CARDIORESPIRATORY FITNESS WITH CARDIOVASCULAR RISK FACTORS IN YOUNG ADULT MEN

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INTRODUCTION

Obesity is negatively and high physical fitness positively associated with cardiovascular health. The risk for mortality have shown to be lower in overweight or obese individuals with high physical activity (PA) or cardiorespiratory fitness (CRF) compared to lean individuals with low CRF [1,2]. These findings indicate that high PA and/or CRF may have a counterbalancing effect on mortality and cardiovascular health. Most of the previous studies have investigated the counterbalancing effects of only CRF or PA in combination with obesity, and to a less extent of muscular fitness to CVD risk factors. Therefore, the purpose of present study was to investigate whether the two components of fitness are independently associated with selected clustered cardiovascular risk (CVD) factor. Secondly, the aim was to answer the question of whether the clustered risk factor is more strongly related to overweight or fitness.

METHODS

749 voluntary young men participated (25±5 yrs.). Muscular endurance index (MEI) consisted of push-ups, sit-ups and repeated squats (reps./min.) whereas maximal strength index (MSI) of maximal isometric force of leg extension and bench press. The mean of z-scores of each muscular endurance test formed a muscular endurance index (MEI), and the mean of maximal strength tests formed a maximal strength index (MSI). Cardiorespiratory fitness (VO_2max) was determined by using an indirect graded cycle ergometer test until exhaustion. Furthermore, waist circumference was measured. The likelihood for selected clustered CVD risk factors were defined, when an individual had two or more risk factors with the following cut-points: plasma glucose (>6.1 mmol/L), triglycerides (>2.0 mmol/L), high-density lipoprotein (HDL) (<1.0 mmol/L), low-density lipoprotein (LDL) (>3.0 mmol/L) and blood pressure (systolic blood pressure >140 mmHg and/or diastolic blood pressure >90 mmHg).

Participants were divided with quintiles into five groups for WC, CRF, MEI and MSI. The individuals within the lowest 20% of fitness were considered to have low fitness, whereas all others (above the first quintile) were considered to have moderate-to-high fitness in CRF, MEI and MSI. WC was divided to increased WC (≥94 cm) and normal WC (<94 cm) [3].Thus, the four categories used in the present study were normal waist circumference and low fitness, normal waist circumference and moderate-to-high fitness, increased waist circumference and low fitness and increased waist circumference and moderate-to-high fitness. Multinomial logistic regression was used to estimate the odd ratios and the 95 % CI for the OR using models with different combination of covariates (age, smoking, CRF, MEI, MSI, leisure time physical activity (LTPA)).

RESULTS

MEI and MSI were not associated with reduced likelihood for selected clustered risk factor in normal WC [OR 1.31 (95% CI 0.39-4.38)], [0.60 (0.19-1.95)] or increased WC [1.38 (0.54-3.50)], [0.76 (0.33-1.76)] after adjustment for age smoking, CRF and LTPA.

CRF was associated with reduced likelihood for clustered risk factor in individuals with normal WC [2.93 (1.15-7.46)], whereas no significant difference was evident in individuals with increased WC [1.40 (0.61-3.23)], after adjustment for age, smoking, MSI, MEI and LTPA.

There was no significant difference in likelihood for clustered CVD risk in individuals with normal WC and low fitness when compared to increased WC and moderate-to-high fitness in MEI and CRF after adjustments. However, individuals with normal WC and low MSI had significantly lower likelihood for clustered risk [0.29 (0.09-0.94)] when compared to increased WC and high MSI after adjustments for age, smoking, CRF, MEI and LTPA.

DISCUSSION

Moderate-to-high cardiorespiratory fitness was related to decreased likelihood for clustered CVD risk factor in individuals with normal waist circumference independent of muscular fitness but could not counterbalance the risk related to abdominal overweight. Therefore, abdominal overweight was more strongly related to clustered CVD risk factor than fitness which highlights the importance of weight management in prevention of CVD risk factors. Furthermore, the present results suggest that aerobic training may be more effective than resistance training in prevention of CVD risk factors. It is however of noteworthy, that resistance training has other health benefits (e.g prevention of sarcopenia) and it may be further speculated that the type of resistance training which induces training response also to cardiovascular system is beneficial for cardiovascular risk factors.

CONCLUSION

In conclusion, the present study showed that increased waist circumference is more strongly related to clustered CVD risk factor than fitness. However, moderate-to-high cardiorespiratory fitness was related to decreased likelihood for clustered CVD risk factor. Moreover, aerobic training may be more effective than resistance training in prevention of clustered CVD risk factor.

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ORAL PRESENTATION 4

Friday Oct. 26th
11:30 – 13:30
(Auditorium D)

11:30 – 11:45
Geir Vegge
Acute effects of vibration on 1RM performance during knee extension exercise

11:45 – 12:00
Ritva Taipale
Acute effects of a strength training session on endurance running

12:00 – 12:15
Olav Vikmoen
The effects of one- and three-set strenght training on strenght and lean body mass gains in upper and lower body in untrained women

12:15 – 12:30
Simon Walker
Neuromuscular fatigue during constant versus variable resistance loadings in young and older men

12:30 – 12:45
Moritz Schumann
Acute neuromuscular and endocrine responses and recovery to single session combined endurance and strength loadings with different exercise orders: implications for training

12:45 – 13:00
Lawrence W Judge
The quadratic nature of the relationship of strength to performance among shot putters

13:00 – 13:15
Angeliki Stasinaki
The effect of strength and power training on throwing performance: compound vs.complex training

13:15 – 13:30
Boris Jidovtseff
Modeling relationships between jump height, ground contact time, reactivity and stiffness

ACUTE EFFECTS OF VIBRATION ON 1RM PERFORMANCE DURING KNEE EXTENSION EXERCISE

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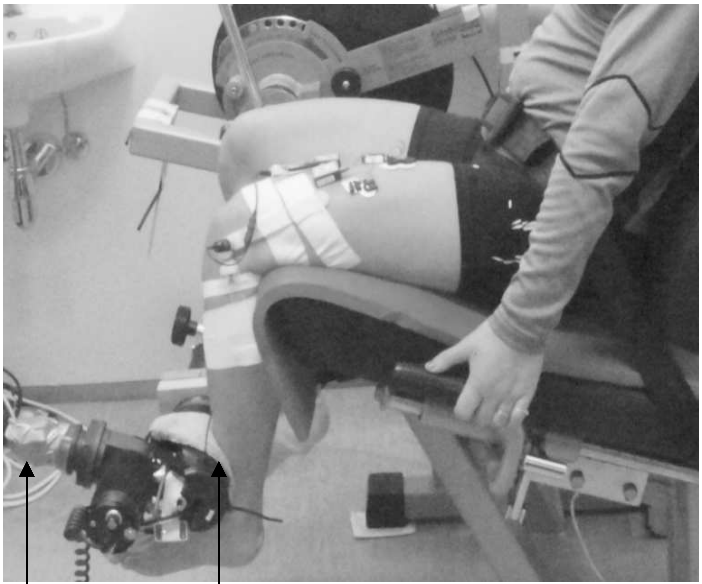
INTRODUCTION

Several studies have shown that vibration during exercise can enhance strength and maximal power performance (Turner et al 2011, Mileva et al 2006, Rønnestad 2009, Rønnestad et al 2012). The effects seems to be affected by many factors, such as vibration frequency, type of vibration: vertical or oscillating/ rotating (Marin et al 2010), maximum acceleration values (Bazett- Jones et al 2008) and training status (Rønnestad 2009). It has been suggested that the acute performance enhancing effects of vibrations are related to an increased EMG activity. Rønnestad 2009 found acute effect of whole body vibration 50 Hz (amplitude 3mm) on half squat 1RM performance, compared to no vibration conditions, standing at a vibration platform. Exposure to vibration 20 Hz and 35 Hz (both amplitude 3mm) did not cause any differences in 1RM compared with no vibration conditions. Rønnestad 2012 found that an increased power output was accompanied by higher EMG starting values and EMG_{peak} values of investigated thigh muscles during 50 Hz whole body vibration compared with no vibration condition. Cardinale et al found that the acute EMG_{rms} response of m Vastus lateralis at 30 Hz vibration, was significantly higher than for 40 and 50 Hz, measured when standing in the half squat position for 60 seconds at an vibration platform. The majority of studies focusing on vibration have investigated effects of whole body vibration on a vibration platform. In the present study we have investigated acute vibration effects of 32 Hz on 1RM performance during the sitting knee extension exercise.

METHODS

21 healthy untrained women (mean± SD: age 21 ± 2 yr, height 170 ± 7 cm, body mass 65 ±11 kg) participated in the study. The subjects had avoided regular strength training during the last 6 months. One legged leg extension (left) was tested with and without 32 Hz vibration. Each subject was tested twice, separated by at least 4 days and no more than 10 days. Both test days included vibration and no vibration conditions. The study was designed and carried out in a randomized crossed- over manner and the order of conditions was changed at test day two. Each test day started with a 5 minute jogging session at a treadmill with no inclination, at an intensity corresponding to 11 at Borgs 6-20 scale (fairly light). The two test conditions were separated by a 8 minute break. Each test condition started with lifting light weights before the 1RM test. When vibration was applied, it was turned on 2 seconds before the lift started and turned of two seconds after the lift was finished. For both conditions, surface EMG was measured for left m. Vastus lateralis, left m Vastus medialis, left m Rectus femoris and left m Biceps femoris.

The EMG data were recorded using a Telemyo DTS wireless system (Noraxon Inc., Scottsdale, Arizona, USA). Seniam recommendations were used for electrode position (http://seniam.org/) and dual electrodes, product 272, inter electrode distance 20 mm (center to center) were used. The recorded EMG signals were downsampled to 1500 Hz, highpass filtered using a cut off frequency of 10 Hz and lowpass filtered using a 500 Hz cut off frequency. EMG_{peak} values were determined as the mean of the highest coherent 250 milliseconds. A mechanical goniometer type Noraxon DTS was used to identify the knee joint positions and accelerometers, type Noraxon DTS3D Accelerometer Sensor, were used to determine the vibration frequency and the peak accelerations. Doing this, one of the accelerometers was fixed to a steady point (steal plate) between the vibration unit and the footpad, and the other at tuberositas tibia. Both accelerometers were fixed with double sided sticky tape. The vibration frequency was measured to 32 Hz at both positions. The actual maximum accelerations values will be presented at the ICST congress. EMG dataset were obtained only from 17 of the 21 persons, due to problems with the EMG recordings.



Vibration unit

Footpad

Figur 1: Picture of the test setting.

RESULTS

We show that 32 Hz vibration resulted in 3.2 ± 5.6% increase for 1RM compared to no vibration conditions ($p<0.05$). 32 Hz vibration also evoked an increased EMG_{peak} activity compared to no vibration conditions in all the measured muscles: m. Vastus lateralis 42 ± 36%, m. Vastus medialis 26 ± 33%, m. Rectus femoris 17 ± 23%, and m. Biceps femoris 22 ± 30 % (all $p\leq 0.05$).

DISCUSSION

The major finding in the present study was an increased 1RM performance under the vibration condition. The improved 1RM was accompanied by increased EMG_{peak} activity. This study can not easily be compared to other studies due to differences in exercises investigated and the way vibration was applied. Nevertheless, the increased 1RM performance accompanied by increased EMG_{peak} activity is in accordance with the findings of Rønnestad et al 2012, though they used a higher vibration frequency. The mechanism for the enlarged EMG values is not clear. It is suggested in Cochrane 2011 that possible mechanisms for enlarged EMG activity involves enlarged muscle activation, increased spinal reflexes and increased motor unit synchronization.

CONCLUSION

Exposure of 32 Hz vibration caused acute increased 1RM performance and increased EMG_{peak} values in young healthy untrained women in the sitting knee extension exercise.

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ACUTE EFFECTS OF A STRENGTH TRAINING SESSION ON ENDURANCE RUNNING

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INTRODUCTION

Recreational endurance runners often combine endurance and strength training into a single session to save time knowing that resistance training increases strength and power of the working muscles, while also improving neuromuscular characteristics of running. It is important to remember that endurance and strength training cause divergent responses that may contribute to a phenomenon known as the "interference effect" as described by Hickson 1980 [1]. Nevertheless, the effect of a strength training session on a subsequent endurance session has not been thoroughly examined. It is hypothesized that a strength training session performed immediately prior to endurance exercise may produce fatigue that can, in turn, modify neuromuscular and cardiorespiratory responses typically produced by a session of endurance training alone. A typical endurance exercise session, on the other hand, does not cause as much neuromuscular fatigue as strength training sessions because of fundamental differences in force production. Endurance exercise only requires repetitive low force production and even maximal uphill running does not induce maximal muscle activation [4]. In contrast, strength exercises require high muscle activation during lifting/pushing of heavy loads which is significantly more strenuous for the neuromuscular system. The purpose of this study was to examine the acute neuromuscular and cardiorespiratory responses to a combined strength and endurance exercise loading versus an endurance exercise loading alone.

METHODS

Twenty- two subjects with a recreational endurance running background (age 21-45 years, n = 12 men n = 10 women) were recruited to participate in this study. All subjects completed two loadings: endurance exercise (E) and a combined strength training session followed by endurance exercise (SE) in a random order. The strength training session focused on the leg extensors and included maximal (3x5-8reps at 75-80% 1RM) and explosive (3x8-10reps at 30-40% 1RM) squat and leg press exercises. The endurance exercise consisted of running for 60 minutes on a 200m indoor track at an intensity between lactate threshold and respiratory compensation threshold. Maximal bilateral isometric strength (MVC) and muscle activation of vastus lateralis and vastus medials (VL+VM EMG) and countermovement jump (CMJ) were measured pre, mid, and post loadings. Running economy (RE) in terms of oxygen consumption (ml·kg·min-1), respiratory exchange ratio (RER) and heart rate (HR) were measured pre, post and during the E loading.

RESULTS

Maximal strength (MVC) decreased significantly in men, but not in women, from pre to post in E and in both men and women from pre to post in SE (figure 1). The decrease in MVC of men following S was significantly greater than the decrease in strength induced by E alone. Muscle activation during MVC of VL+VM in SE men decreased significantly ($p < 0.05$) between pre and post, while no changes were observed in VL+VM EMG of E men or in either group of women.

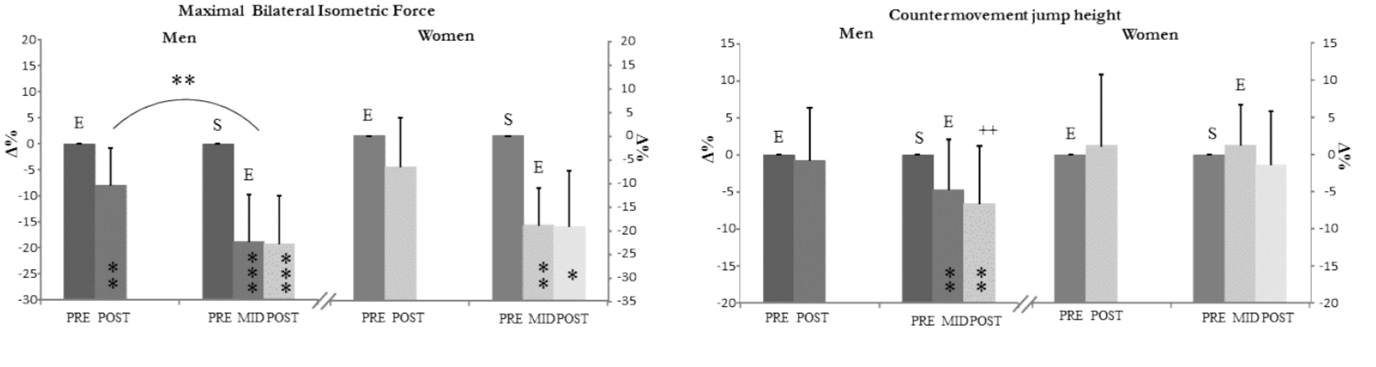

Figure 1. Change (Δ%) in maximal bilateral isometric force and countermovement jump height relative to pre measurements *,**, *** = $p < 0.05$, 0.01. 0.001 from pre, ++ = $p < 0.01$. ** = $p < 0.01$ between groups.

Countermovement jump height decreased significantly in men between pre-, mid- and post- of SE but not in E (figure 1). In women, no significant decrease in CMJ height was observed in either loading.

Running economy was decreased at the beginning of the E loading after S when compared to that when endurance was performed alone in both men and women (table 1). In men, RE at the end of the endurance loading in both SE and E were similar whereas in women, the difference in RE remained significant, although small in magnitude. Heart rate during the endurance loading of both E and SE loadings increased steadily throughout the loadings with no differences in the pattern of HR increase between men and women and no differences in HR observed between loadings. Respiratory exchange ratio did not differ significantly between loadings although a significant decrease was observed over the loading in both men and women for E and SE.

Table 1. Running economy, respiratory exchange ratio and heart rate during the endurance exercise loading. *,**, *** = $p < 0.05$, 0.01. 0.001 from pre to post and mid to post ^{a,b} = $p < 0.01$ between loadings ^{c} = $p < 0.05$ between loadings.

			PRE	POST		MID	POST
RUNNING ECONOMY	**MEN**	**E**	43.3 ± 3.7 ^{a}	44.7 ± 3.7 *	**SE**	45.0 ± 4.0 ^{a}	45.3 ± 4.4
(ml · kg · min $^{-1}$)	**WOMEN**	**E**	37.9 ± 3.3 ^{b}	38.5 ± 3.8 ^{c}	**SE**	39.1 ± 3.4 ^{b}	39.3 ± 3.5 ^{c}
RESPIRATORY EXCHANGE RATIO	**MEN**	**E**	0.93 ± 0.03	0.89 ± 0.03 ***	**SE**	0.93 ± 0.03	0.87 ± 0.04 **
	WOMEN	**E**	0.90 ± 0.03	0.85 ± 0.03 ***	**SE**	0.89 ± 0.04	0.84 ± 0.04 ***
HEART RATE	**MEN**	**E**	151 ± 8	160 ± 10 ***	**SE**	154 ± 11	162 ± 10 **
(bpm)	**WOMEN**	**E**	159 ± 13	166 ± 12 ***	**SE**	160 ± 17	167 ± 17 **

DISCUSSION

Running economy was clearly affected by performing S prior to E in both men and women, while the present mixed maximal and explosive strength training session with its volume and intensity did not affect RER and HR when a strength training session preceded E. Decreased RE indicating an increased need for oxygen at a constant running speed suggests that the strength session has affected either neuromuscular or metabolic factors involved in RE. In both men and women, the significant decreases in MVC of SE provides evidence to the theory that neuromuscular running characteristics were affected by fatigue produced by the strength session. In men, the parallel decrease in muscle activation of VL+VM EMG further supports this theory. S exercise also led to decreases in explosive strength measured by CMJ in men, but interestingly did not cause significant decreases in explosive strength in women. It has previously been shown that women are less fatigable than men in both maximal strength training sessions [2] and in explosive strength training sessions [3]. This appears to be true with the present mixed maximal and explosive strength training where maximal strength of men decreased somewhat more than women, and explosive strength decreased in men, but not in women. Thus, while the relative intensity of the loadings were the same for men and women, gender differences appear to exist. The present loadings produced less neuromuscular fatigue in women than men, particularly in terms of explosive strength, whereas cardiorespiratory factors including HR, and RER follow similar patterns in both men and women.

CONCLUSIONS

Fatigue induced by a strength training session immediately prior to endurance running exercise affects neuromuscular characteristics of maximal strength, muscle activation and explosive strength in men and maximal strength in women. In both genders, this mixed maximal and explosive strength training loading induced decreases in neuromuscular function that affected performance during running exercise.

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THE EFFECTS OF ONE- AND THREE-SET STRENGHT TRAINING ON STRENGHT AND LEAN BODY MASS GAINS IN UPPER AND LOWER BODY IN UNTRAINED WOMEN

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INTRODUCTION

Previous studies have shown that 3-set strength training is superior to 1-set strength training to increase strength and cross sectional area (CSA) in the leg muscles, while no difference was found between 1-set and 3-set in strength and CSA gains in the upper body in previously untrained men (Rønnestad et al., 2007; Paulsen et al., 2003). In both these studies total training volume (upper body + lower body) was identical in the groups. Whether the same effects of 1-set vs. 3-set strength training exist in untrained women remains to be examined. Consequently, the purpose of this study was to compare the effects of single- and multiple set strength training on muscle hypertrophy and strength gains in untrained women.

METHODS

Twenty six untrained women between 18-40 years old were randomly assigned to two different training groups. Both groups performed a 12-week strength training program with 3 training sessions per week. One group trained 3 sets in the leg exercises and 1 set in the upper body exercises (3L-1U, n=13) and the other group trained 1 set in the leg exercises and 3 sets in the upper body exercises (1L-3U, n=13). Both groups trained 3 leg and 5 upper body exercises per training session. Training intensity started with 10 repetition maximum (RM) sets during the first week and was progressively increased to 7 RM sets during the last weeks. Strength (1RM) was tested in two of the leg exercises (leg press and leg extension) and two of the upper body exercises (seated chest press and biceps curl) before and after the intervention period and during training week 4, 7 and 10. Body composition was measured by dual-energy X-ray absorptiometry (DEXA) before and after the training period.

RESULTS

The increase in 1RM load from before to after the intervention period in the tests for the lower body combined (leg press and leg extensions) was significantly higher in the 3L-1U group than in the 1L-3U group (44±11% vs. 32±11%, $p < 0.05$, figure 1). The 1RM load for the upper body tests combined (seated chest press and biceps curl) increased more in the 1L-3U group than in the 3L-1U group (63±18% vs 41±11%, $p<0.05$, figure 1).

The 1RM tests during the intervention period showed that it was only at the post test the 3L-1U group had significantly larger increase in 1RM load in the lower body tests. The 1L-3U group had a larger increase in 1RM load in the upper body tests at week 7, 10, and at post.

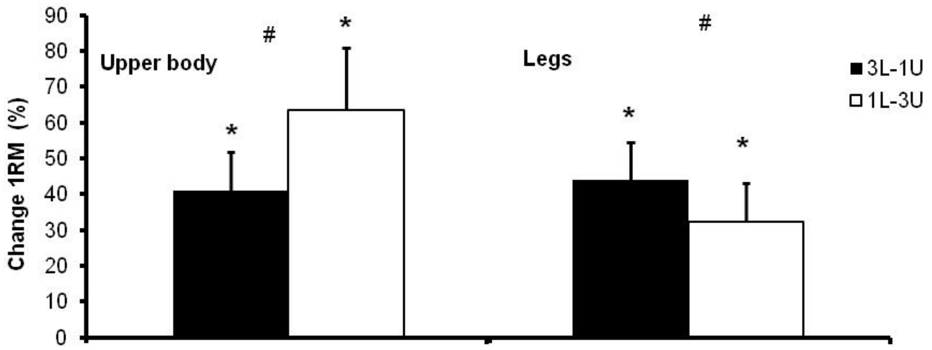

Figure 1. Changes in 1RM for the upper body tests combined (left) and the leg tests combined (right) for both groups. * significant increase from pre ($p < 0.01$). # significant different in change between groups ($p<0.05$).

The lean body mass of the legs increased significantly only in the 3L-1U group (5.4 ± 4.4%, $p < 0.01$). The increase in the 1L-3U group was not significant (3.0 ± 5.7%, $p = 0.22$). The difference in percent change between the groups was not significant.
The lean body mass of the arms increased significantly in both groups, with no significantly difference in percent change between the groups (3L-1U: 5.8 ± 5.1%, 1L-3U: 9.4 ± 7.7%).

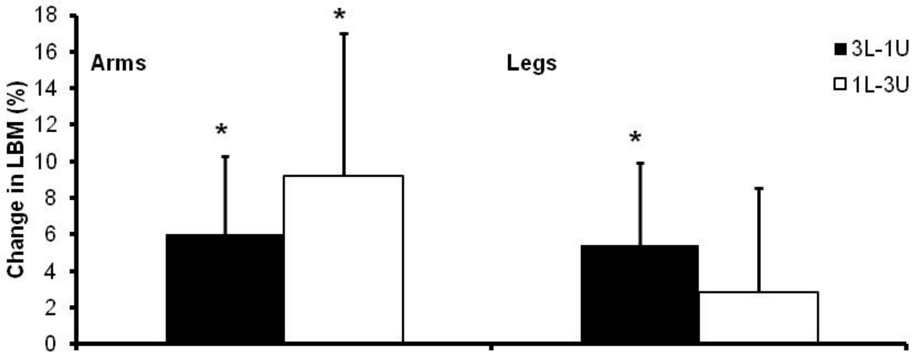

Figure 2. Changes in LBM for the arms (left) and the legs (right)for both groups. * significant increase from pre ($p<0.05$).

DISCUSSION
This study indicates that 3-set strength training is superior to 1-set strength training with regard to gains in strength in both leg muscles and upper body muscles during a 12 week strength training program for untrained women. The same trend was evident for LBM in both arms and legs but the differences between groups were not statistically significant. Other training variables such as intensity of training, total training volume, movement velocity, number of training sessions and strength test specificity were similar in the two groups. Therefore the greater increase in strength with 3-set training was probably because of larger stimuli for hypertrophy with multiple sets. This is different from results previously showed on men, were 3 set training were superior to 1-set training only in the leg muscles (Rønnestad et al., 2007; Paulsen et al 2003).

CONCLUSIONS
In untrained women 3-set increased strength more than 1-set strength training in both leg muscles and upper body muscles during a twelve week training program. The same tendency could be seen for changes in LBM but the different between groups were not significant.

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NEUROMUSCULAR FATIGUE DURING CONSTANT VERSUS VARIABLE RESISTANCE LOADINGS IN YOUNG AND OLDER MEN

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INTRODUCTION

The use of variable resistance devices, where the external resistance changes throughout the range of motion in accordance with the human torque capabilities, has been shown to produce greater acute neuromuscular fatigue compared to constant resistance devices (2, 4). However, the mechanisms underlying the greater magnitude of fatigue have not been identified, which may aid in prescription of training programs. Furthermore, previous studies have investigated young men only. As older men have been shown to have different neuromuscular properties, and consequently respond to loading differently (i.e. lower magnitude of fatigue) compared to young men, the present study investigated acute neuromuscular fatigue in young and old men during constant vs. variable resistance knee extension loadings.

METHODS

Twelve young men (28 ± 5 yr) and 13 older men (65 ± 4 yr) completed 4 acute knee extension loading sessions, each separated by 7 days. All subjects were healthy and recreationally active, but none had participated in systematic strength training. As recreational strength trainers typically aim to improve both maximum strength capabilities as well as muscle mass, the present study used a maximal strength loading protocol (15 sets of 1RM) and a hypertrophic loading protocol (5 sets of 10RM) with both constant and variable resistance settings (total of 4 loadings sessions). Three minutes rest between sets was given during maximal strength loadings, while 2 minutes of rest was given during hypertrophic loading. The knee extension device was specially modified (David 200, David Health Solutions Ltd, Finland) to enable either constant or variable resistance and was fitted with strain gauge sensors and a locking system. Seven days prior to the first loading session, cross-sectional area of the vastus lateralis muscle was obtained by ultrasound and the subject's concentric bilateral 1RM was determined (loading was performed bilaterally). Six ultrasound images were collected using the devices extended-field-of-view feature (Model SSD-**α**10, Aloka Co Ltd, Japan) at 50 % femur length, with the mean of the closest 4 images being used forfurther analysis. Each subject's 1RM was determined following warm up sets of 70 % estimated 1RM (10 reps), 80 % estimated 1RM (5 reps), and 90 % estimated 1RM (2 reps), by increasing the external load by 5 kg once the subject was able to lift the load to a 180° knee angle (full knee extension). No more than 4 maximal attempts were required to determine 1RM. A series of unilateral tests (right leg) were performed to assess the impact of loading pre- and immediately post-loadings. Following warm-up and placement of surface electromyogram (EMG) electrodes on the vastus lateralis (VL) and vastus medialis (VM) muscles, 3 maximal isometric knee extension contractions of 3-5 s duration were performed at a knee angle of 107° with a superimposed twitch evoked directly to the quadriceps muscles once peak torque was achieved. A control twitch was given on the resting muscle 2 s after contraction cessation. Voluntary activation was calculated according to the formula of Bigland-Ritchie et al. (1). The stimulation intensity was determined by obtaining the maximum torque response in a resting condition with the addition of a further 25 % to ensure supramaximality (Model DS7AH, Digitimer Ltd, UK). Surface EMG signals were sampled at 2000 Hz and band pass filtered (20-350 Hz) and analysed over a 500 ms epoche immediately before the superimposed twitch for amplitude using root mean square (rms) and median frequency (Hamming, 1024 data points). Thereafter, maximum M wave properties of the VL and VM muscles were examined via femoral nerve stimulation in a resting condition. Finally, a fingertip blood sample (20 μL sample placed into 1 ml hemolysing solution) was taken to assess blood lactate and analysed using the manufacturers instructions (EKF diagnostic, Biosen, Germany). Repeated measures ANCOVA (2 groups Å~ 4 loadings Å~ 2 time) assessed main effects of torque and repeated measures ANOVA (2 groups Å~ 4 loadings Å~ 2 time) assessed M wave and median frequency data. Bonferroni adjustments were applied as post hoc tests.

RESULTS

At baseline, young men had significantly greater isometric torque (231 ± 42 vs. 185 ± 26 Nm, $p < 0.01$), larger VL cross-sectional area (26 ± 7 vs. 22 ± 2 cm2, $p < 0.05$), and greater maximum twitch torque (78 ± 21 vs. 60 ± 10 Nm, $p < 0.05$) and maximum rate of twitch torque development (1753 ± 377 vs. 1417 ± 271 Nm.s-1, $p < 0.05$) than the older men. Maximum strength loadings (15 Å~ 1RM) led to reductions in both external load and maximum isometric torque in both age groups. However, variable resistance resulted in significantly greater decrease in external load in young men only (-11 ± 7 vs. -6 ± 3 %, $p < 0.05$). In both young and older men, maximum twitch torque decreased significantly following variable resistance loading only ($p < 0.05$). Also, while voluntary activation and EMG amplitude decreased following both variable and constant resistance loadings in young men, only variable resistance loading caused decreases in these variables in older men. Hypertrophic loadings (5 Å~ 10RM) led to large reductions in maximum isometric torque following in both groups. However, in young men, variable resistance caused greater decreases than constant loading (- 50 ± 15 vs. 44 ± 11 %, $p = 0.058$). This was accompanied by significant decreases in voluntary activation (-7 ± 8 %, $p < 0.05$), median frequency (-12 ± 13 %, $p < 0.05$), and increases in M wave duration (23 ± 23 %, $p< 0.05$), whereas there were no changes following constant resistance loading. Similarly, in older men, only variable resistance loading caused increases in M wave duration (45 ± 40 %, $p< 0.05$) and decreases in median frequency (-14 ± 10 %, $p < 0.05$). Young men had higher blood lactate concentration than older men after both hypertrophic loadings ($p < 0.01$).

DISCUSSION

The use of variable resistance loading resulted in greater neuromuscular fatigue than constant resistance in young men in accordance with previous studies (2, 4). However, no differences between variable and constant loadings were observed in older men. This may be due to the overall lower magnitude of fatigue in older men, which may be partly explained by their baseline neuromuscular properties and subsequently higher blood lactate concentrations. In young men, maximum torque production was decreased to a greater extent following both maximal strength and hypertrophic variable resistance loadings vs. constant resistance loadings. This was accompanied by greater peripheral fatigue, as assessed by M wave properties and EMG median frequency, and also greater central fatigue, as assessed by voluntary activation, during hypertrophic loading. These results suggest interference to action potential propagation and reduced activation of fast twitch fibres (3). During variable resistance maximal strength loading, young men demonstrated greater reductions in maximum twitch torque (i.e. peripheral fatigue) vs. constant resistance loading. Similar observations were made in older men, suggesting that using variable resistance during maximal strength loading induces similar effects on older men. However, neither the concentric nor maximum isometric torque decreases between variable vs. constant resistance loadings were significant in older men.

CONCLUSION

Variable resistance devices induce a greater magnitude of both central and peripheral fatigue in young men, which may contribute to adaptations during long-term training. Indications of greater fatigue between variable vs. constant resistance loadings were observed in older men, however, it may be that greater volume and/or intensity may be needed to create a similar magnitude of response as observed in young men.

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ACUTE NEUROMUSCULAR AND ENDOCRINE RESPONSES AND RECOVERY TO SINGLE SESSION COMBINED ENDURANCE AND STRENGTH LOADINGS WITH DIFFERENT EXERCISE ORDERS: IMPLICATIONS FOR TRAINING

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INTRODUCTION

Both the neuromuscular and endocrine systems have been shown to play an integrative role in acute responses to endurance and strength loading and prolonged training. Research often shows that strength and especially power development are compromised when prolonged periods of strength training are combined with endurance training sessions performed on separate days (3, 2) and on the same day (1). Considering the importance of acute responses in the development of chronic adaptations, endurance and strength exercises performed on separate days elicit divergent acute neuromuscular and endocrine responses and recovery patterns which might in part explain the interference of strength development when both forms of training are combined. The aim of the present study was to investigate acute neuromuscular and endocrine responses, recovery and long term adaptations to single session combined endurance (E) and strength (S) loadings and training with different exercise orders in previously untrained men.

METHODS

A total of 42 previously untrained men were recruited to take part in this study (mean±SD; age 29.2±4.9 years; height 178.3±5.2cm; body mass, 75.9±8.6kg). Subjects were randomly assigned to two groups and performed either an E+S (n=21) or S+E (n=21) loading. Following this experimental loading, 32 subjects (E+S, n=14; S+E, n=18) continued training for 24weeks (2x12wks) by keeping their corresponding exercise order. Subjects were first tested for their E (VO_{2max}) and S (1RM and maximal isometric leg press, MVC) performance (T_0). Subjects then conducted the loading order of their corresponding group. S (30min) was performed on a dynamic leg press including low load explosive and high load maximal and hypertrophic bilateral actions (3x10 reps at 40% of 1 RM and 1x3 reps at 75% of 1 RM and 3x3 reps at 90-95% of 1 RM with 3 min of rest between the sets as well as 2x10 reps at 75% of 1 RM and 2x10 reps at 80-85% of 1 RM with 2min of rests between the sets) and E (30min) was conducted as continuous cycling at 65% of maximal Watts. Maximal bilateral isometric force (MVC_{max}), rapid force production as force produced in 500ms (MVC_{500}) and serum hormone concentrations of total testosterone (T) were determined PRE, MID (following E or S, respectively) and POST both loading conditions and were repeated after recovery of 24h and 48h. During training the measurements for S performance in both groups were repeated after 12 (T_1) and 24 (T_2) weeks. Subjects performed 2 combined sessions (2x E+S or S+E) for 12 weeks and increased the frequency and volume by adding another combined session every second week (5x E+S or S+E per 2 weeks) for the remaining 12 weeks. S training focused primarily on leg muscles but included some upper body and trunk exercises while the intensity was progressively increased. S training included sub-maximal, heavy and maximal loads. E training included both continuous and intermittent training sessions and was progressively increased from low to high intensity with a duration between 30 and 60min per training session.

RESULTS

Acute responses and recovery: Both loading groups induced significant acute reductions in MVC_{max} (Fig.1A) at MID (E+S, -14%, $p<0.001$; S+E, -21%, $p<0.001$) and POST (E+S, -27%, $p<0.001$; S+E, -22%, $p<0.001$) compared to PRE. The relative change in MVC_{max} in S+E at MID was larger ($p=0.056$) than that of E+S. The reduction from MID to POST was significant in E+S (-13%, $p<0.001$) but the values remained unaltered in S+E. MVC_{max} recovered in both loadings significantly from POST to 24h (E+S, +22%, $p<0.001$; S+E, +21%, $p<0.001$) so that at 24h and 48h no significant differences compared to the pre-loading values were found. MVC_{500} was significantly reduced in both loading conditions at MID (E+S, -15%, $p<0.001$; S+E, -17%, $p<0.01$) and POST (E+S, -26%, $p<0.001$; S+E, -18%, $p<0.001$) compared to PRE, whereby the reduction from MID to POST was significant only in E+S (-11%, $p<0.001$). MVC_{500} recovered in both loadings significantly from POST to 24h (E+S, +17%, $p<0.001$, S+E +13%, $p<0.05$) but values remained significantly reduced compared to PRE in E+S (-9%, $p<0.01$). Serum T concentration (Fig.1B) significantly increased in E+S at MID (+16%, $p<0.001$) and remained slightly increased at POST (+7%, $p>0.05$) compared to PRE. In S+E serum T concentration was slightly increased at POST (+16% compared to MID, $p<0.01$; +10% compared to PRE, $p>0.05$). The difference between E+S and S+E at MID was significant (difference 20%, $p<0.001$). Serum T concentrations significantly decreased in E+S at 24h of recovery compared to PRE (-13%, $p<0.05$) and remained reduced at 48h (-11% compared to PRE, $p=0.068$) but did not differ in S+E from pre-loading values at 24h and 48h of recovery.

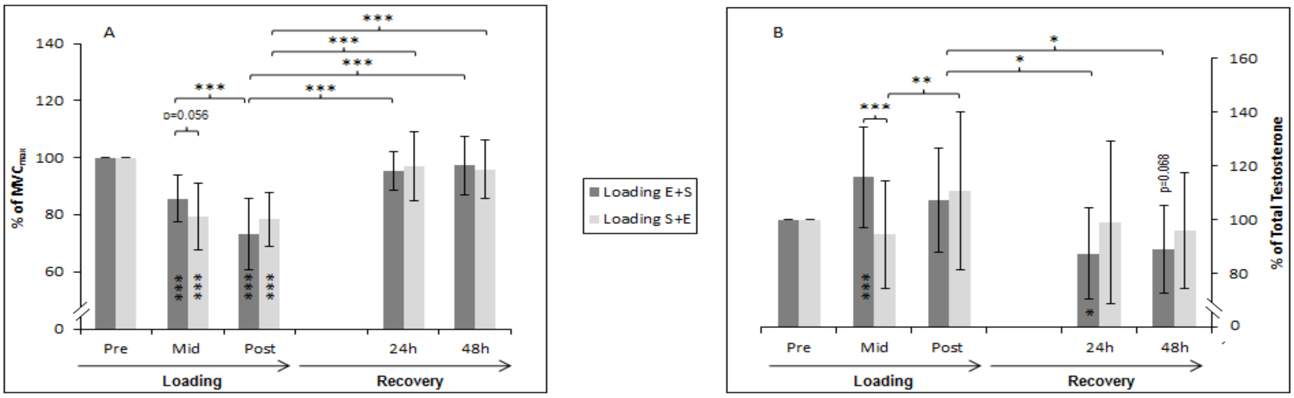

Fig 1. Acute responses and recovery of MVC_{max} (A) and serum testosterone (B). *$p<0.05$; **$p<0.01$; ***$p<0.001$

Prolonged training adaptations: Both training groups showed significant increases in 1RM at T_1 (E+S, +8%, $p<0.01$; S+E, +12%, $p<0.001$) and T_2 compared to T_1 (E+S, +5%, $p<0.01$; S+E, +5%, $p<0.05$) and T_0 (E+S, +13%, $p<0.001$; S+E, +17%, $p<0.001$). MVC_{max} was significantly increased in both groups at T_1 (E+S, +10%, $p<0.01$; S+E, +9%, $p<0.05$) and remained increased at T_2 compared to T_0 (E+S, +11%, $p<0.01$; S+E, +13%, $p<0.05$). Similarly, MVC_{500} was significantly increased at T_1 (E+S, +18%, $p<0.05$; S+E, +18%, $p<0.01$) and did not further increase significantly at T_2 (E+S, +21%, $p<0.05$; S+E, +19%, $p<0.01$).

DISCUSSION

This study showed that single session combined endurance and strength loadings led to significant acute reductions in MVC_{max} and MVC_{500}, whereas this decrease was somewhat smaller at MID and somewhat larger at POST in E+S compared to S+E. Since after recovery of 24h no significant decreases in MVC_{max} and MVC_{500} compared to pre-loading values were anymore found, the study does not provide evidence for an order effect during recovery of neuromuscular performance. However, decreased testosterone concentrations following the E+S loading condition during recovery at 24h and 48h suggest a prolonged regeneration from an endocrine perspective when continuous cycling of moderate intensity exercise precedes a strength loading session consisting of explosive, maximal and hypertrophic loads in untrained men. The present results support evidence of different recovery time courses between the neuromuscular performance and endocrine function. Although these findings indicate the important difference during recovery, both loading conditions performed over 24 weeks did not lead to differences in strength adaptations. Particularly this emphasizes the importance of a well planned loading-recovery distribution in previously untrained subjects when prolonged periods of single session combined endurance and strength loadings are performed.

CONCLUSION

The present study suggests decreased serum testosterone concentrations during recovery up to 48h when endurance cycling was followed immediately by a strength loading protocol of varying loads and, thus, indicates prolonged regeneration following this exercise order. However, if trainability is increased and the needs of recovery decreased by prolonged systematic training, the exercise order does not seem to significantly influence strength and power development in previously untrained young men.

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THE QUADRATIC NATURE OF THE RELATIONSHIP OF STRENGTH TO PERFORMANCE AMONG SHOT PUTTERS

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INTRODUCTION

The competitive performance of a shot putter in track and field can be characterized as a very aggressive display of strength, power, and technique [1]. The shot put event in track and field utilizes a technical pattern that attempts to create a summation of forces by creating torques between different parts of the body via stretch reflexes. All of these torque-creating positions are performed in hundredths of a second. For this reason, it is essential that the body be finely tuned to optimally perform these techniques. Given the explosive nature of throwing events and the proper contraction sequencing that must take place, training routines are designed to emphasize strength, power and flexibility. Strength and conditioning coaches that do not have adequate access to information about throwing are left wondering which exercises produce the best results with the athletes they are working with and if certain types of athletes respond better to different exercises. The purpose of this study was to investigate the relationship of the 1RM in the power clean, back squat and bench press to shot put event performance.

METHODS

A survey instrument was developed to collect data regarding national level collegiate shot putters in the United States. The 24 males (22.2 ± 2.2 years) and 29 females (22.5 ± 2.8 years) athletes had a mean personal best performance of 16.93 ± 2.45 meters for the men and the women 15.24 ± 2.85 meters. The sample included several national qualifiers, two national champions in shot put and three Olympians. Trends in the relationship between 1RM power clean, back squat, bench press and personal best in the shot put for male and female athletes were assessed via general linear model polynomial contrast analysis, and subsequent polynomial regression.

RESULTS

General linear model analysis revealed both significant omnibus tests of the models (male likelihood ratio $\chi 2 = 56.716$, $p \leq 0.001$, female likelihood ratio $\chi 2 = 102.516$, $p \leq 0.001$) and significant linear and quadratic trends in the data for male and female shot put athletes when comparing 1RM power clean to personal best distance (male: Wald $\chi 2 = 179.937$, $p \leq 0.001$ linear, Wald $\chi 2 = 8.598$, $p=0.003$ quadratic; female: Wald $\chi 2 = 738.577$, $p \leq 0.001$ linear, Wald $\chi 2 = 134.864$, $p \leq 0.001$ quadratic). This same trend held true for the back squat (Omnibus Test: male likelihood ratio $\chi 2 = 61.341$, $p \leq 0.001$, female likelihood ratio $\chi 2 = 69.077$, $p \leq 0.001$). For the back squat both linear and quadratic trends in the data were observed to be significant (male: Wald $\chi 2 = 197.543$, $p \leq 0.001$ linear, Wald $\chi 2 = 63.543$, $p=0.003$ quadratic; female: Wald $\chi 2 = 161.571$, $p \leq 0.001$ linear, Wald $\chi 2 = 41.828$, $p \leq 0.001$ quadratic). Similar overall results were found for the bench press lift (Omnibus Test: male likelihood ratio $\chi 2 = 62.960$, $p \leq 0.001$, female likelihood ratio $\chi 2 = 119.635$, $p \leq 0.001$). Both linear and quadratic relationships were found for the bench press (male: Wald $\chi 2 = 182.730$, $p \leq 0.001$ linear, Wald $\chi 2 = 30.937$, $p=0.003$ quadratic; female: Wald $\chi 2 = 1131.273$, $p \leq 0.001$ linear, Wald $\chi 2 = 20.222$, $p \leq 0.001$ quadratic).

A multiple linear regression method was utilized to create a model to explain the variance in shot put personal best using the three 1RM measures. The unstandardized predicted values were saved and examined for both linear associations and quadratic associations with actual personal bests. The quadratic regression of the predicted values on the actual produced stronger associations than the linear fit (male: quadratic $r=0.887$ vs linear $r=0.876$; female: quadratic $r=0.940$ vs linear $r=0.917$). Neither the predicted values from the linear regression nor the subsequent quadratic transformation resulted in a significant difference from the actual personal best values ($p>0.05$), and Hotelling's T-square analysis did not demonstrate a significant difference among correlations.

DISCUSSION

Weight room one repetition maximums (1RM) have been shown to be related to performance in the throwing events [2, 3]. However, the shot put in track and field itself uses a much lighter load (4 kg for women, 7.26 kg for men) than those used frequently during weight training sessions. Strength and conditioning coaches have many decisions to make when designing resistance training programs. Though it has long been known that strength is a necessary component of the performance in track and field throwing events [1,2,3], the relationship of the individual lifts to competitive season performance is not well understood. In discussions with college coaches, one can find a lack of consistent thought about which of the three lifts (the bench press, back squat or power clean) is the most important for the shot put event. Most sources of training information for coaches suggest that all three lifts need to be covered within a training plan for a shot put athlete. It would appear that based upon these results that both significant linear and quadratic trends exist that relate 1RM measures of the power clean, back squat and bench press to the personal best of shot put athletes.

CONCLUSION

The understanding that there are both linear and curvilinear trends in the association between strength and performance potentially can enrich the understanding of this association. The quadratic regression analysis revealed that athletes towards the outer ranges of performance in the shot put require greater levels of increasing strength in order to obtain the associated distances.

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THE EFFECT OF STRENGTH AND POWER TRAINING ON THROWING PERFORMANCE: COMPOUND vs. COMPLEX TRAINING

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INTRODUCTION

Throwing performance is based upon muscular strength and power (Newton and Kraemer, 1994). It has been shown that strength training alone can improve throwing performance, by improving muscle strength/mass (Terzis et al., 2008). The combination of resistance training and plyometric training yields greater results than either method alone for performance (Adams et al., 1992, Baechle and Earl, 2000). Moreover, a recent study have shown that compound training (strength and power training in different sessions) as well as complex training (strength and power in paired-exercises in the same session) can improve vertical jump height (VJH) and mean power output during countermovement jumping (Mihalik et al., 2008). However, there are few scientific data regarding the impact of strength training, power training or the combination of them in the form of compound or complex training, on throwing performance. Therefore, aim of this study was to investigate the effect of two different training programs Compound and Complex, of 6-week duration, on throwing performance in novice throwers.

METHODS

Twenty six young moderately-trained males were divided into three groups: Compound (CPD, N=9), Complex (CPX, N=9) and Control group (CNT, N=8). The training program was performed 3/wk for 6 weeks and the CPD group performed strength and power sessions in alternative days, whereas the CPX group performed them in pairs: one strength exercise followed by one power exercise (Ebben, 2002). Two subjects from the CPD group did not finish the training program due to personal reasons. Strength training exercises included leg press, bench press and semi-squat on a Smith machine while power training contained the same exercises performed in a ballistic manner as well as 3x8 drop jumps from 45cm. On a strength training day, the CPD group performed 4x6RM and on a power training day 4x8reps at 30% 1RM plus 3x8 drop jumps from 45cm. At each training day the CPX group performed 2x6RM and 2x8reps at 30% 1RM (paired-exercises) plus 3x8 drop jumps from 45cm. Throwing performance was tested with three different exercises; a) the underhead throw, b) the overhead backward throw and c) the one-arm standing throw (legs in parallel). Assessment of one repetition maximum (1RM) for leg press, bench press, and semi-squat was performed according to previous reports (Baechle and Earl, 2000). Power production and VJH were evaluated during the CMJ test according to previous reports (Mihalik et al., 2008). A 2x2 repeated-measures analysis of variance was used to analyze all performance data. Fisher's LSD post hoc tests were used to determine pairwise differences when significant F ratios were obtained. For all statistical tests, a probability level of $p < 0.05$ was established to denote statistical significance.

RESULTS

After the training period, throwing performance was increased by 9.2% ($p= 0.02$) only in the CPD group (Figure 1). Maximal strength (1RM) increased from pre to post training, in leg press by 21,3% and 26% ($p< 0.01$), for CPD and CPX, respectively, in bench press by 5% and 18% ($p< 0.05$), in squat by 30% and 36% ($p< 0.01$). A significant interaction was observed for leg press and squat ($p= 0.007$ and $p= 0.015$, respectively) indicating that the increase observed in CPX was greater than the increase observed in CPD. Only the CPD training significantly improved performance and power production in VJH (4%, $p= 0.017$, Figure 2).

Table 1. Characteristics of the subjects participated in the three different groups.

	Age (yrs)	Mass (kg)	Height (cm)
Compound (N=7)	22.27 ± 2.7	73.5 ± 4.57	177 ± 2.78
Complex (N=9)	21.9 ± 2.3	77.3 ± 7.97	179 ± 0.06
Control (N=8)	21.4 ± 1.5	72.5 ± 11.17	178 ± 0.05

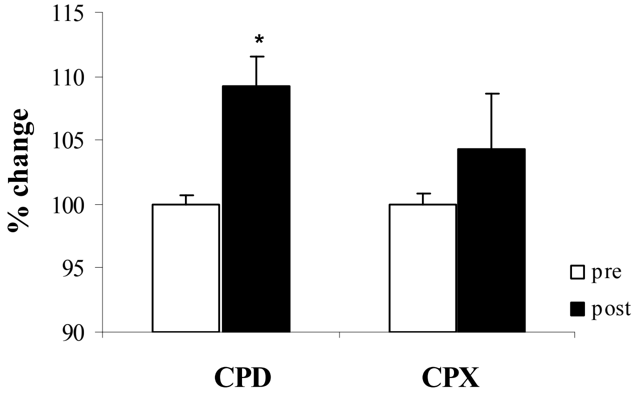

Figure 1. Training-induced changes to throwing performance. * Significant ($p < 0.05$) difference from pre to post training.

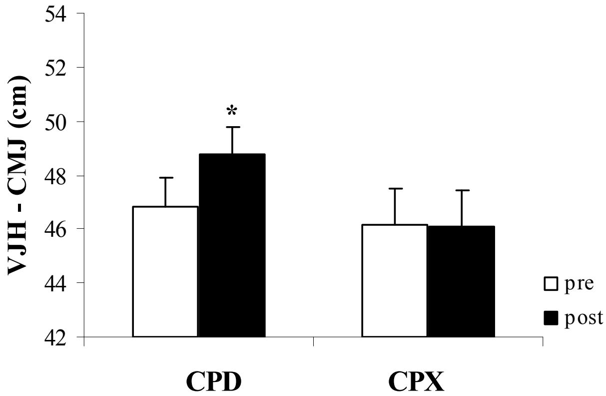

Figure 2. Training-induced changes to vertical jump height (VJH) during countermovement jumping (CMJ). * Significant ($p < 0.05$) difference from pre to post training.

DISCUSSION

The results suggest that throwing performance can improve more after 6 weeks of strength and power training with compound than with complex training in moderately-trained individuals. This differential improvement seems not be connected with changes muscular strength. Rather it seems to be linked with changes in muscular power since vertical jumping performance was not significantly increased after complex training.

CONCLUSION

These results might suggest that novice throwers can increase their throwing performance by implementing strength and power training stimuli in alternative training days, at least during short training periods up to 6 weeks. It seems that performing strength and power training exercises one after the other in the same training day is not favorable for throwing performance.

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MODELING RELATIONSHIPS BETWEEN JUMP HEIGHT, GROUND CONTACT TIME, REACTIVITY AND STIFFNESS.

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INTRODUCTION

Plyometric muscular actions involve the stretch shortening cycle (SSC) in a sports specific manner. In some cases, it is very important to jump high (volleyball, basketball, ski jumping, etc.). In other cases, it is important to jump as high as possible with time constraints and consequently short and intense impulses (rebound, volleyball, etc.) are needed. In other contexts it could also be important to have very short and stiff impulse (sprinting, rebounds, tennis, etc.). Recent research has demonstrated that muscular stiffness during a jump was not linked to the jump performance [1]. A practical consequence is that both training modalities are very different for these two muscular qualities. Another consequence is that training follow up should take into account muscular qualities required for performance. Traditional jumping tests such as the squat jump and countermovement jumps provide incomplete information. Reactivity tests are difficult to standardize and could lack reliability. Stiffness appears very difficult to assess in field conditions. The aim of this study was to develop an original plyometric test that assesses at the same time the four main SSC characteristics: jumping high, ground contact time, reactivity and stiffness.

METHODS

Twenty healthy subjects (22±2 yr, 1.73±0.09 m, 65±11 kg) participated in this study and were tested twice, one week apart, using the same exercise modalities. The testing protocol started with squat jump (SJ) and counter movement jump (CMJ) tests. Three familiarization trials were followed by three measured trials. After these two tests, all subjects performed the "plyometric profile" that consisted of continuous jump tests (CJ) following 5 different modalities. For each modality, subjects received a specific instruction:

1. CJ-CT: jump 6 times with the intention to reduce as much as possible the ground contact time. Jump height has to be very low.
2. CJ-CTR: jump 6 times with the intention to reduce as much as possible the ground contact time. Jump height has to be a little higher.
3. CJ-R: jump 6 times with the intention to reduce as much as possible the ground contact time and at the same time jump as high as possible.
4. CJ-RJH: jump 6 times with the intention to jump as high as possible. The ground contact time can be increased and a little knee flexion is recommended
5. CJ-JH: jump 6 times with the intention to jump as high as possible. Take time to flex the knee at each landing

Each modality was performed two times. Ten subjects started with the CJ-CT and followed the continuum until CJ-JH while the ten other subjects did the opposite.

The Myotest pro accelerometer (Myotest, Switzerland) was vertically attached to an elastic belt on the subject's hip, according to the manufacturer's instructions. Vertical jump height (JH) was measured for all the tests. Ground contact time (CT), reactivity index (RI = flying time/CT) and stiffness (Stif = Fmax/vertical displacement during impulse) were also assessed for all continuous jumps. Classical descriptive statistics were used in the present study. Inter-session reproducibility was measured with a specific coefficient of variation (CV)[2]. A dependent t-test was used to determine significant differences. Mathematical modeling was used to describe the relationships between JH, CT, RI and Stif.

RESULTS

Table 1 presents descriptive data and coefficients of variation for the four parameters measured at each continuous jump test. JH and CT increased from CJ-CT to CJ-JH while Stif decreased ($p<0.001$). RI reached the highest value at CJ-R. JH reproducibility was excellent for CJ-RJH and CJ-JH. CT reproducibility was good for CJ-CT and CJ-TCR. In comparison with other parameters, Stif reproducibility was lower with CV's ranging from 17 to 48%. There was no significant difference between session 1 and session 2. CMJ jumping height (33.7±5.8) presented no difference with CJ-JH but was significantly greater than SJ (32.8±5.5cm)($p<0.05$).

Table 1 – Descriptive data and reproducibility analysis (CV) for the "plyometric profile" test.

		CJ-CT	CJ-TCR	CJ-R	CJ-RJH	CJ-JH
JH(cm)	Mean(SD)	6.6 (2.0)	14.1 (3.0)	24.3 (4.0)	31.3 (5.3)	33.0 (5.9)
	CV (%)	28	18	11	5	3
CT(ms)	Mean(SD)	108 (11)	117 (13)	148 (29)	277 (75)	446 (85)
	CV (%)	6	8	11	25	15
RI	Mean(SD)	2.1 (0.3)	2.9 (0.4)	3.1 (0.5)	2.0 (0.5)	1.2 (0.3)
	CV (%)	10	8	7	25	17
Stif ($kN.m^{-1}$)	Mean(SD)	90 (23)	67 (19)	42 (15)	13 (7)	5 (2)
	CV (%)	17	20	24	48	32

The figures presented all the relationships established between JH, CT, RI and Stif after mathematical modeling.

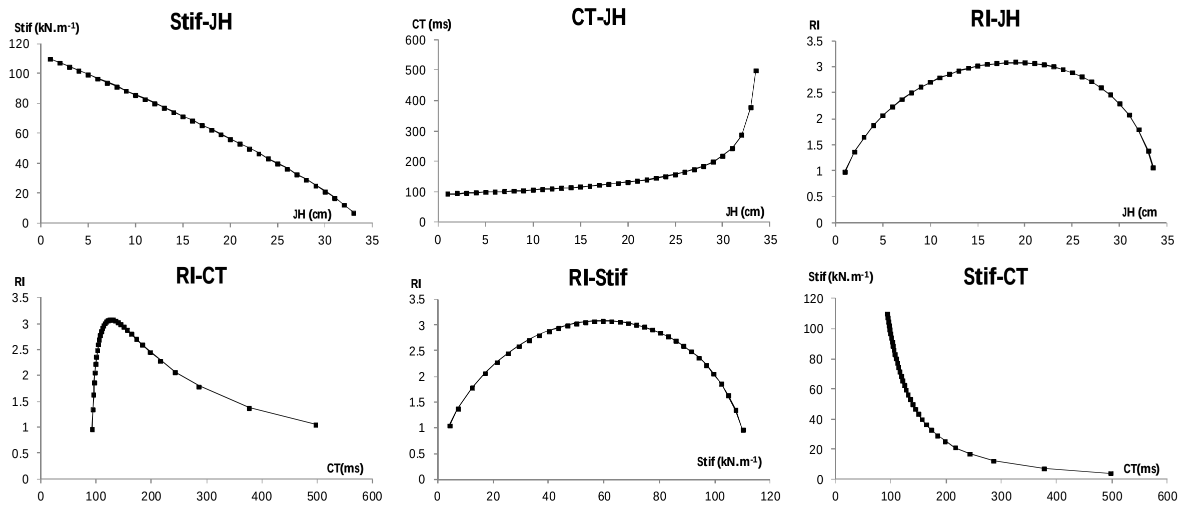

Figure 1 – Relationships between JH, CT, RI and Stif established after mathematical modeling.

DISCUSSION

The "plyometric profile" test built on five progressive modalities of continuous jumps allowed measurement of the variation of four plyometric parameters (JH, CT, RI and Stif) inside a continuum going from maximal jumping height to minimal ground contact time. Mathematical modeling was then successfully used to describe all the relationships between these four parameters. Such an approach is not limiting the athlete evaluation to jumping height ability but also affords measurement of reactivity and stiffness qualities, which are important in many sport actions. The "plyometric profile" could be performed in the field with a simple and accessible accelerometer. However, mathematical modeling requires specific software that needs to be developed.

CONCLUSION

The present study presents the "plyometric profile" potential. It could be very useful for plyometric acute assessment and longitudinal follow up.

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POSTER WITH DEFENSE 1

Thursday Oct. 25th,
14:30 – 16:30
(Sports Hall)

The poster session starts at 14:30 pm. Each presenters are given 5 minutes for presentation, including question and answers. The Chair person leads the session and presenters will present in order 1 to 12.

Poster 1
Vidar Andersen
Effects of grip width on loading and muscle activation in the lat pulldown

Poster 2
Jiří Baláš
Strength characteristics differ in young and adult climbers of the same climbing abilitye

Poster 3
Nicolas Berryman
Effects of training cessation on muscular performance: a meta-analysis

Poster 4
Josipa Bradić
Effects of unilateral strength training on contralateral one - legged standing balance

Poster 5
Carlos Carvalho
Strength and Muscular power training in the school context

Poster 6
Raša Dimitrijević
Differences in indices of maximum force of leg extensors within the selected populations1

Poster 7
Christoph Ebenbichler
The influence of direct pre-activation on the starting performance of elite ski cross athletes

Poster 8
Lawrence W Judge
The impact of experience on the use of advanced coaching techniques

Poster 9
Alexey Netreba
Effects of muscle strength potentiation by contralateral excitation

Poster 10
Christian Raschner
Development of a multi-axial mechatronic training and testing device for high perfomance ski racers

Poster 11
Lars Edwin Samnøy
Does training with elastic rubber band supported exercises facilitate improvements in performance and muscular adaptions in high level powerlifters?

EFFECTS OF GRIP WIDTH ON LOADING AND MUSCLE ACTIVATION IN THE LAT PULLDOWN

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INTRODUCTION

The anterior lat pulldown is one of the most common exercises for strengthening the back muscles. However, different variants of the exercise exist. For example, the exercise can be performed with different grip widths. We are not aware of any studies investigating how pronated grip width affects absolute strength and concomitant muscle activation. Therefore, the aim of this study was to compare the 6-RM load and electromyographic (EMG) activity using three different pronated grip widths.

METHODS

After one familiarization session, fifteen healthy males (24 ± 4.4 years (mean ± SD), 180 ± 10 cm and 81,3 ± 7.9 kg) with > one year of resistance training experience, performed 6-RM in the lat pulldown with narrow, medium and wide grip in a counterbalanced and randomized order. The lat pulldown started with fully extended arms and ended when the bar was pulled underneath the chin (concentric phase) before returning to starting position (eccentric phase). The lifting tempo was self-selected, but in a controlled manner. The subjects were instructed to keep their truncus in a vertical position and minimize movement during the test. Narrow, medium and wide grip of the barbell were defined as 1, 1.5 and 2 times the biacromial distance, respectively. The EMG was recorded from four different muscles (latissimus dorsi, trapezius, biceps brachii and infraspinatus) on the side of the dominant arm. Statistical significance was accepted at $p \leq 0.05$.

RESULTS

The loads lifted with narrow (80.3 ± 7.2 kg) and medium grip (80 ± 7.1 kg) were significantly higher compared to wide grip (77.3 ± 6.3 kg), (p = 0,02 and 0.02 respectively). There were no differences in muscle activation when the entire movement was considered (concentric and eccentric phase). Analyzing the concentric phase separately revealed that biceps brachii had greater activation using the medium compared to the narrow grip ($p = 0.03$). In the eccentric phase, latissimus dorsi and infraspinatus had greater activation using the wide grip compared to the narrow (p = 0.04 and 0.02 respectively). There was similar lifting time between the three grip widths.

DISCUSSION

The differences in loading are most likely caused by biomechanical differences. The lever arm from the shoulder joint increases as the grip gets wider and can explain the reduction in loading using the wide grip. Earlier training experience and therefore specific training adaptations could also affect the performance, favouring the grip width the subjects are used to train with. Further, similar EMG activity was recorded from the different grip widths which indicate that relative intensity is more important than grip width for activating the muscles. It should be noted that only one pair of electrodes were used on each muscle and the EMG recordings were limited to four muscles.

CONCLUSION

Wide grip provided lower 6-RM strength than the medium and narrow grip. During the entire movement, at the same relative intensity, muscle activation using narrow, medium and wide grip in the lat pulldown, was similar. Generally, the results show that the influence of grip widths in the lat pulldown on muscle activation is minimal. Therefore, bodybuilders and recreational trainers can expect that muscle hypertrophy gains will be similar for these grip widths.

STRENGTH CHARACTERISTICS DIFFER IN YOUNG AND ADULT CLIMBERS OF THE SAME CLIMBING ABILITY

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INTRODUCTION

The style of contemporary sport climbing has changed to steep, overhanging routes resulting in the need for high levels of upper body and finger strength. The typical climber is characterised by small stature and low body fat [1, 2]. It is generally indicated that high scores in finger strength, finger and shoulder girdle endurance are associated with high levels of climbing performance [3]. Very little literature is devoted to the physiological aspects of climbing in children. Watts et al. [4] characterise young competitive climbers as relatively small, with low body mass, low sums of skinfolds and high grip strength to body mass ratio, noting differences in body composition between climbers and non-climbing athletes despite similar BMI values.

To our knowledge, there are no data evaluating upper body strength and endurance in elite young climbers and very little is known about the relationship of the anthropometric and the strength/endurance characteristics in young and adult athletes. The aim of the study was to assess anthropometric and strength characteristics in young and adult elite climbers.

METHODS

Thirty five (20 boys with the mean age 15.6, s = 1.6 yrs, 15 girls 14.8, s = 1.9 yrs) young and fifty nine (45 males 27.5 s = 8.1 yrs, 14 females 25.5, s = 5.5 yrs) adult climbers with the climbing ability ranging from 7+ to 10+ on the UIAA (Union Internationale des Associations d'Alpinisme) scale took part in the study. The four groups divided according to the age (<18; ≥18 yrs) and the sex were of similar climbing abilities (median 8+ UIAA). Anthropometric (height, weight, body fat) and strength characteristics (grip strength, finger hang, bent-arm hang) were assessed. The differences between young and adult climbers were analysed by 2x2 ANOVA with factors sex and age.

RESULTS

The characteristics of body mass, height, extra-cellular/body-cellular mass (ECM/BCM) ratio, body fat, climbing experience, and climbing volume for adult and young elite climbers are presented in table 1. The results of upper body strength/endurance tests and information about metres climbed per week are presented in Figure 1.

Despite no differences in climbing ability among male and female young and adult athletes, young male and female climbers had higher ECM/BCM ratio, were stronger in finger-hang test (males 76.4, s =19.8 s; females 84.7, s = 25.1), had less climbing experience than adult climbers within the same sex (finger hang males 60.2, s = 16.9 s; females 57.2, s = 17.5 s).

Table 1: characteristics (mean ± standard deviation) of body mass, height, extracellular/ body cellular mass (ECM/BCM) ratio, body fat, climbing experience and climbing volume for adult and young elite climbers

	Sex	N	Body mass (kg)[1,2]	Height (cm)[1,2]	ECM/BCM [1,2]	Fat (%) [2,3]	Climbing experience (years)[1]	Climbing volume (metres climbed/week) [1]
Adult climbers	F	14	58.2±5.8	167.9±6.0	0.82±0.12	13.3±1.6	6.9±2.2	452±152
	M	45	72.0±6.6	179.4±7.0	0.72±0.07	10.4±2.0	9.0±6.6	387±197
Young climbers	F	10	48.0±11.3	161.2±12.2	0.91±0.10	14.5±3.5	5.4±2.0	657±308
	N	12	57.3±10.1	169.9±9.9	0.79±0.07	9.0±2.2	5.0±2.3	539±475

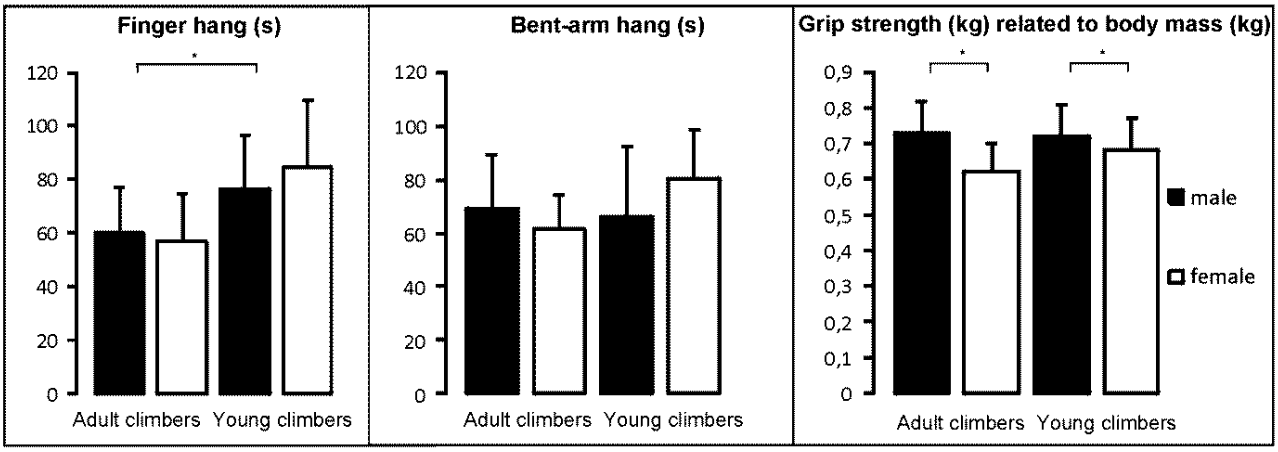
[1] significant differences between adults and youth α<0.05
[2] significant differences between males and females α<0.05
[3] significant interaction between adults, youth and sex of climbers α<0.05;

DISCUSSION

The finger hang test was the only one strength/endurance test where significant differences between adults and youth were found despite similar climbing ability in both groups.

Young climbers had on average by 20 s longer hold on the 2.5 edge than adults. The result is surprising and we can only speculate about the causes. There can be an influence of technique and tactic of the ascent. Adults had longer climbing experience than youth and climbing experience is considered as significant predictor of climbing performance [5]. Lower finger endurance in adults is, therefore, compensated by better technique and tactic of the climb. The other explanation could be the lower body mass of youths. Although the finger hang is a test using the body mass of participants, the smaller and lighter climbers could benefit from their posture. Nevertheless, it was not confirmed in the second endurance test bent-arm hang.
To assess body composition, bio impedance analysis was used. Our findings confirm that low percentage of body fat is closely related to climbing performance and are in agreement with other findings [1, 6]. We have not found differences between young and adult climbers in body fat percentage and we are in agreement with the study of Watts et al. (2003) that young competitive climbers have similar body fat to elite adult climbers. There were, however, significant differences in ECM/BCM ratio between youth and adults and males and females which is not surprising because the ECM/BCM ratio is normally lower in children and females [7]. The ratio is used as an indicator of muscular predispositions but its effect on the climbing performance is still hypothetical.

Figure 1: Results in finger hang , bent-arm hang and grip strength related to body mass for adult and young climbers, * denotes significant differences p<0.05



CONCLUSION

The young elite climbers have similar results in body fat percentage, bent-arm hang time, grip strength related to body mass as adult elite climbers. There were, however, found significant differences in finger hang time. The finger hang belongs to the strongest predictors of climbing performance and the enhanced finger endurance in youth is probably compensated by better technique and tactic in adult climbers.

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EFFECTS OF TRAINING CESSATION ON MUSCULAR PERFORMANCE: A META-ANALYSIS

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INTRODUCTION

Muscular strength has been identified as a major determinant of sport performance, both in explosive (1) and long duration events (2), as well as an important contributor to functional performance and health in older adults (3, 4). The capacity of the skeletal muscle to generate a high level of force is a complex interplay between several factors, including muscle fiber type (5), muscle cross-sectional area (6), muscle architecture (7) and neural drive to the muscle (8). Resistance training is a safe and effective intervention to improve these determinants and increase muscular strength, whatever age and sex (9-11). However, according to the principle of reversibility, training induced adaptations are transitory and may disappear when the training stimulus is withdrawn, thus leading to detraining. Detraining has been defined as the partial or complete loss of training induced anatomical, physiological and functional adaptations, as a consequence of training cessation (12). The reasons for such a scenario are numerous in an individual's life: e.g. illness, injury, travel, loss of motivation or post-season break in competitive athletes. Identifying of strength loss kinetics once resistance training ceases is important to design successful tapers and return to optimal fitness for competitive athletes and more generally for the individualization of exercise training prescriptions, whatever the characteristics of the population. The literature examining this issue is very heterogeneous in terms of training/training cessation characteristics, muscular strength tests and measures and population characteristics. Although there is consensus among narrative reviews that training cessation leads more or less rapidly to detraining (12-15), methodological heterogeneity does not allow to make direct comparisons between studies or to nuance the overall detraining effect according to sex, age, training status or other relevant variables such as the duration of training cessation.

METHODS

Seven databases were searched using relevant terms and strategies. Studies were eligible for inclusion if: 1) they implemented a training intervention followed by a training cessation period and give relevant details about the procedures, 2) the outcome included valid tests and measures of the upper or lower limb muscular performance in healthy humans, and 3) the paper included the number of participants and all necessary data to calculate effect sizes. Data sets reported in more than one published study were only included once. One hundred and three of 284 potential studies met these criteria and were included in the analysis. Standardized mean difference in muscular performance was calculated and weighted by the inverse of variance to calculate an overall effect and its 95% confidence interval. A random effects model was used because of methodological differences between studies. Subgroup analyses of moderators variables including population and training cessation characteristics was performed in the presence of statistical heterogeneity (as measured by the I^2).

RESULTS

The overall SMD indicated a detrimental effect of training cessation on all components of muscular performance, since we found a moderate decrease in muscular endurance (SMD [95% CI] = -0.62 [-0.80 to -0.45], $P < 0.01$, $I^2 = 11.0\%$) and a small decrease in maximal force (SMD [95% CI] = -0.46 [-0.54 to -0.37], $P < 0.01$, $I^2 = 75{,}6\%$) and maximal power (SMD [95% CI] = -0.20 [-0.28 to -0.13], $P < 0.01$, $I^2 = 69.9\%$). We found a dose-response relationship between the amplitude of SMD and the duration of training cessation. The effect of training cessation was found to be larger in older people (≥ 65 years old) for maximal force ($P < 0.01$), maximal power ($P < 0.05$) and muscular endurance ($P < 0.05$). The effect of training cessation was also larger in inactive people for maximal force (adjusted *P*

< 0.05) and maximal power (adjusted $P < 0.05$) when compared with recreational athletes, but not for muscular endurance (adjusted $P > 0.05$). Finally, we did not found any difference between males and females, whatever the type of muscular performance ($P > 0.05$).

DICUSSION

The purpose of this investigation was to assess the effects of training cessation on the different expressions of muscular strength, including maximal force, maximal power and muscular endurance by means of a systematic review of the literature and a meta-analysis. We found a moderate decrease in muscular endurance and a small decrease in maximal force and maximal power. This detrimental effect was found to differ according to the duration of training cessation, age and training status, but was not influenced by sex or the characteristics of previous training.

CONCLUSION

This meta-analysis provides a framework that can be useful for the optimization of taper strategies and return to fitness in competitive athletes, and more generally for exercise prescription in the general population.

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A complete list of all references included in this meta-analysis is available upon demand.
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EFFECTS OF UNILATERAL STRENGTH TRAINING ON CONTRALATERAL ONE - LEGGED STANDING BALANCE

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INTRODUCTION

Strength training of ipsilateral limb leads to the changes in the contralateral limb [2, 3, 6, 8, 9, 10, 12, 18] This phenomenon is called cross education, cross excercise, cross training or cross transfer, and the effects is called contralateral effects, cross training effects or cross transfer effects. It has been known for 118 years. It was first noticed and reported 1894th by the Mrs. Emily M. Brown [4]. Today this phenomenon is well-known in the field of motor control and it is one of the most important indicators that the changes in strength and power, caused by unilateral strength training, is the result of neural adaptations [11]. Studies have shown a positive correlation between strength of lower extremity and balance among older [7, 14] and younger person [17]. It is known that hip isokinetic exercise of the dominant leg leads to the improvement in contralateral balance performance [9]. It is not known how unilateral concentric contractions of knee extensors and flexors, and ankle dorsi and plantar flexors on isokinetic dynamometer influence on contralateral balance performance. So, the aim of this study is to determine the impact of this type of unilateral training on contralateral one-legged standing balance in physically active women.

METHODS

Subjects. 30 young, healthy, and physically active women (age: 21 yrs., mass: 60 kg, height: 67 cm, percent body fat: 26%) were randomly allocated to one of two groups: 1) control group (n=15), 2) experimental group (n=15). *Training program.* The training program consisted of unilateral concentric contractions of knee extensors and flexors, and ankle dorsi and plantar flexors and it was performed on isokinetic dynamometer (Biodex System 3, Biodex Corporation, Shirley, NY). The training velocity was 60°/s for knee, and 30°/s for ankle. Over the 4-week program the training volume increased progressively with the increase in sets number, starting first with two (first training), then three (from second to fifth training) and finally with four sets (from 6th to 12th training). *Testing procedure.* Each participant was tested on two occasions: 1) prior to commencement of training (Pre), and 2) one week after the completion of the 4-week training period (Post). The testing procedure included one-legged standing balance measurement, followed by leg strength (i.e. muscle function) measurement. *One - legged standing balance***.** Single-limb postural stability was assessed on a Biodex Stability System, level 5 (Biodex, Shirley, New York, USA). BSS was used in a numerous of studies before (1, 13, 15, 16, 9). The measures of dynamic balance included overall stability index scores (OSI). The OSI represents the variance of foot-platform displacement in degrees from a level position, in all motions during a test. A high stability score indicates poor balance. *Data analyses.* Pre and Post training Means and SDs were calculated for ipsilateral (trained) and contralateral (untrained) one – legged standing balance in both group. T-test for independent (EXP – CON) and dependent (Pre-Post) samples was set at $p < 0,01$.

RESULTS

The results of t-test for dependent samples showed that there is no statistically significant difference in BALANCE test of dominant and undominant leg between groups in Pre testing. For this reason, statistically significant changes in the ipsilateral and contralateral single leg balance between Pre and Post testing (Table 1.) attributed to the effects of training program.

Table 1. Pre and Post training descriptive data (Means ± SD) for the balance test of the ipsilateral (trained) and contralateral (untrained) leg in the experimental and control group. T-test for dependent samples was set at $p < 0,01$.

BALANCE	**EXP (Pre)**	**EXP (Post)**	**CON (Pre)**	**CON (Post)**
IPSILATERAL	2,07 (0,82)	1,34* (0,57)	2,34 (0,77)	2,27 (0,86)
CONTRALATERAL	1,91 (0,58)	1,61* (0,50)	2,41 (0,62)	2,37 (0,65)

t-test for independent samples showed that those effects are statistically significant between EXP and CON group in both trained and untrained legs (Fig.1).

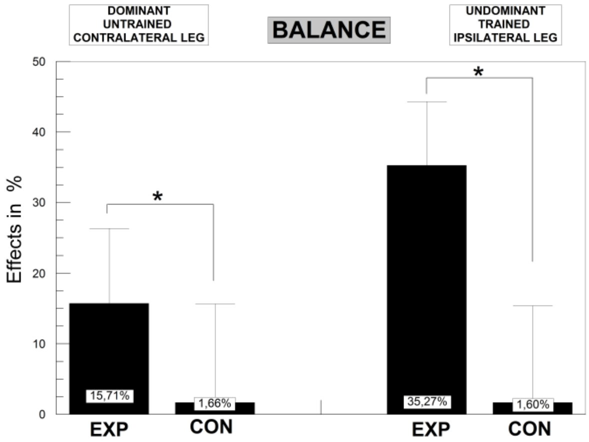

Fig.1. The percent of changes in BALANCE test OSI in EXP and CON group in contralateral (untrained) and ipsilateral (trained) leg. *t-test* for independent samples was set at p<0,01.

DISCUSSION

The results of this study show that unilateral concentric strengths training of lower extremities improve balance of ipsilateral leg for 35 %, and contralateral for more than 15 %. The results of this study are in accordance with the study from 2011. [9]. These results suggest that contralateral training with unilateral hip isokinetic exercise increases one-legged standing balance of the contralateral limb. In our research were trained muscles that surround the joints relevant for one-legged standing balance. For example, one of important postural strategies in balance preservation is so-called Strategy of ankle joint [5]. According to this Strategy, human body is rotating around ankle joint by principle of the reverse pendulum, therefore; it stands to a reason, that training of strengths muscles that surround ankle joints significantly improves stability and upright standing balance.

CONCLUSION

Obtained results significantly extend our perception about cross education phenomenon, or phenomenon of contralateral strength training effects. Contralateral training effects are relevant and these results could provide the implementation potential in many areas, especially in the field of physical medicine, rehabilitation, prevention of falls and injuries.

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STRENGTH AND MUSCULAR POWER TRAINING IN THE SCHOOL CONTEXT

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INTRODUCTION

Information about strength trainability in children and adolescents is still very limited and much less when it relates to school environments. It is generally agreed that school-aged youth should participate regularly in at least 60 minutes or more of moderate to vigorous physical activity per day which is developmentally appropriate and enjoyable (ACSM, 2010).

Scientific evidence indicates that children and adolescents can significantly increase their muscular strength if given a training programme of adequate intensity, volume and duration (Behm et al. 2008; Faigenbaum and Myer, 2010), i.e., well-designed strength-training programmes which can enhance the muscular strength of children and adolescents beyond that produced by normal growth and development. The main aims of this study are to observe: (i) if motor capacity strength and muscular power, in general, improve in the school context and (ii) if the implementation of a strength training programme has greater gains than in normal physical educational classes (PE).

METHODS

The study involved two groups of 10th graders from Fontes Pereira de Melo secondary school, Porto. It consisted of 15 female participants who were allocated to two groups: a control group with 8 students and an experimental group with 7 students.

The process implied the execution of the following tests to assess muscle strength and muscular power: 60 second push-ups, 30 second abdominals (curl-ups), 2kg medicinal ball throws, static horizontal jumps, sextuple horizontal jumps and 50m runs.

The strength training programme consisted of a set of callisthenic exercises with short dumbbells: calf raises, lunges, half squats, bench press, butterfly, vertical row, abdominal and lower back (2 sets of 10-15 repetitions at ca. 60% 1RM). These exercises were carried out twice weekly and the training program lasted 6 weeks.

RESULTS AND DISCUSSION

As we can see in Table 1, both groups show gains in all the tests between the 1st and 2nd moments of assessment.

In the experimental group, the gains are statistically significant in push-ups, suspension, 2kg medicinal ball throw, sextuple horizontal jumps however the control group also had significant improvement in throwing the medicinal ball and sextuple jumps, which were evidenced in the non-parametric statistics in the Wilcoxon test. This may suggest that normal PE classes and maturation can induce enhancement in physical performance. Although the experimental group showed better changes in all the tests, only in the static horizontal jumps did it have sufficiently greater/robust gains which statistically differentiate it from the control group (p=0.032 in the Mann-Whitney test).

Table 1 – Results of strength and muscular power between the 1st and 2nd moments of assessment in all the tests

		Pre-test	Post-test	Changes		Wilcoxon test
Tests	**Groups**	**Means**	**Means**	**Abs**	**%**	**p**
Abdominal (n)	Control	31,20	32,60	1,40	4,49	0,0590
	Experimental	30,86	38,00	7,14	23,14	0,1500
Push-ups (n)	Control	14,60	16,20	1,60	10,96	0,1570
	Experimental	13,29	16,86	3,57	26,86	0,0270
Suspension (sec)	Control	27,00	27,41	0,41	1,52	0,6840
	Experimental	26,50	28,60	2,10	7,92	0,2230
2kg MB(cm)	Control	522,80	541,00	18,20	3,48	0,0430
	Experimental	686,00	753,00	67,00	9,77	0,0430
Horiz jump (m)	Control	1,48	1,49	0,02	1,08	0,7660
	Experimental	1,64	1,77	0,13	7,66	0,0420
Sextuple (m)	Control	8,95	9,44	0,49	5,47	0,0430
	Experimental	9,89	10,36	0,47	4,77	0,0430
50m run (sec)	Control	10,00	9,93	-0,07	-0,70	0,4960
	Experimental	9,32	9,29	-0,03	-0,36	0,4960

CONCLUSION

This study demonstrated that physical education classes can induce improvement both in strength and muscular power in these female students. It is also true that the organization of physical education lessons whenever focused on the importance of a strength training plan develops even more evident gains. However, the efficacy of the strength training programme was not totally proven, probably due to the limited time of its application.

"If youth strength-training programmes are well designed and sensibly progressed over time, children and adolescents can gain the knowledge, skills, and self-motivation to regularly strength-train as a lifestyle choice" as stated by Faigenbaum, (2011), this is, physical education lessons should not only induce harmonious and healthy physical development but it should also generate well-being together with healthy habits and practises which will accompany children and adolescents throughout life.

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DIFFERENCES IN INDICES OF MAXIMUM FORCE OF LEG EXTENSORS WITHIN THE SELECTED POPULATIONS[1]

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INTRODUCTION

Legs and their respective muscle groups represent the body part that is the most responsible for locomotion in people. Within the given segment, the muscles which anatomically and functionally belong to the leg extensors are predominantly responsible for the quality of locomotion. One of the basic contractile characteristics of the muscles is the ability of power/force realization from the aspect of maximal isometric force as the function of time (McCurdy and Langford, 2005; Nagano et al., 2005). The ability of an individual to perform movements of maximal velocity (high and long jump, acceleration, sprint, changes of direction, etc.) depends on the ability to realize leg extension in a good quality way. Besides the general index, which defines the general/basic level of explosiveness of a certain muscle group / multi-articulation system and which describes explosiveness with respect to the maximum of achieved force (RFDFmax), it is necessary to define the index which primarily contains the information relevant for estimating specific fitness in terms of explosive force/strength (Wu et al., 2003; Nagano et al., 2005). The research was performed with a view to estimating the levels of the maximum force indices in leg extensors in the selected populations of future police officers and physical education teachers. The results obtained can be used for the purpose of improving the segments of training focusing on the development of the observed motor ability among the students of the Academy of Criminalistic and Police Studies (ACPS).

METHODS

The sample consisted of 32 subjects, 12 of whom were the ACPS students (BH=1.808±0.041 m, BM=78.38±5.10 kg, Age=19.67±0.78 years old) and 20 students of the Faculty of Sport and Physical Education (FSPE) (BH=1.831±0.046 m, BM=81.30±6.84 kg, Age=25.15±3.08). The force manifestation was realized though the movements of bilateral extension, dominant leg extension, and non-dominant leg extension; the results were monitored in terms of the maximum values (Fmax), time necessary to perform the movement (tmax), and the maximum development of force per time unit (RFDmax). The obtained results were observed in terms of basic descriptive statistics; the difference of variability between the observed variables was established by the variance analysis - ANOVA; the existing of difference between individual variables was established by using Student's t-test for independent causes.

RESULTS

The results of the basic descriptive statistics bilaterally ACPS students and FSPE students for Fmax: Mean±SD 4086.62±1107.63 N, cV% 27.10, Min 2796.32 N, Max 6423.07 N; Mean±SD 3536.44±637.33 N, cV% 18.02, Min 2505.73, Max 4781.67, respectively. The results for tmax: Mean±SD 1.19±0.38 s, cV% 32.02, Min 0.72 s, Max 1.90 s; Mean±SD 1.18±0.52 s, cV% 44.22, Min 0.60 s, Max 2.93 s, respectively. For RFDmax Mean±SD 3738.27±1551.51 N/s, cV% 41.51, Min 2036.11 N/s, Max 6891.70 N/s; Mean±SD 3426±1281.28 N/s, cV% 37.39, Min 1114.00 N/s, Max 5288.04, respectively. The dominant leg Fmax Mean±SD 2256.97±584.99 N, cV% 25.92, Min 1511.01 N, Max 3437.84 N; Mean±SD 1999.87±455.99 N,
cV% 22.80, Min 1305.29 N, Max 2989.89 N, respectively. For tmax Mean±SD 2.08±0.75 s, cV% 32.02, Min 0.72 s, Max 1.90 s; Mean±SD 1.18±0.52 s, cV% 44.22, Min 0.60 s, Max 2.17 s, respectively. For RFDmax Mean±SD 1279.03±728.05 N/s, cV% 56.92, Min 646.59 N/s, Max 3104.15 N/s; Mean±SD 1965.81±813.10 N/s, cV% 41.36, Min 1090.58 N/s, Max 4289.66 N/s, respectively. For the non-dominant leg Fmax Mean±SD 2260.17±618.29 N, cV% 27.36, Min 1506.65 N, Max 3647.48 N; Mean±SD 1908.99±436.22 N, cV% 22.85, Min 1364.65 N, Max 2741.54 N, respectively. For tmax Mean±SD 1.83±0.42 s, cV% 22.79, Min 0.95 s, Max 2.43 s; Mean±SD 1.00±0.32 s, cV%31.64, Min 0.55 s, Max 1.55 s, respectively. For RFDmax Mean±SD 1289.38±433.77 N/s, cV%

33.64, Min 816.75 N/s, Max 2088.10 N/s; Mean±SD 2066.25±705.83 N/s, cV% 34.16, Min 1007.25 N/s, Max 3435.81 N/s, respectively. The results of Student's t-test for Fmax bilateral, dominant, non-dominant $t=1.792$, $p=0.083$; $t=1.388$ $p=0.175$; $t=1.844$ $p=0.069$, respectively. For tmax $t=0.066$ $p=0.948$; $t=4.478$ $p=0.000$; $t=6.397$ $p=0.000$, respectively. For RFDmax $t=0.586$ $p=0.564$; $t=-2.402$ $p=0.023$; $t=-3.431$ $p=0.002$, respectively. The results of ANOVA for Fmax bilaterally, dominant, non-dominant $F=3.211$ $p=0.083$; $F=1.928$ $p=0.175$; $F=3.548$ $p=0.069$, respectively. For tmax $F=0.004$ $p=0.948$; $F=20.053$ $p=0.000$; $F=40.920$ $p=0.000$, respectively. For RFDmax $F=0.379$ $p=0.543$; $F=5.771$ $p=0.023$; $F=11.772$ $p=0.002$, respectively.

DISCUSSION

The results of the basic descriptive statistics indicate that the ACPS students achieved, on average, better results for the variables of bilateral maximal force, dominant and non-dominant leg. From the aspect of tmax, the ACPS students had longer average time in all three cases, i.e. they developed the maximum force in longer time intervals. As regards the RFDmax variable, the ACPS students had better results in bilateral measuring, whereas they achieved lower values for the dominant and non-dominant measurements. The ANOVA results showed that there was a statistically significant difference between the mean values and variability for the variables of dominant tmax, non-dominant tmax, dominant RFDmax, and non-dominant RFDmax in favour of the FSPE students. The results of Student's t-test indicated that there were statistically significant differences between the mean values of errors for the variables of dominant tmax, non-dominant tmax, dominant RFDmax, and non-dominant RFDmax in favour of the FSPE students.

CONCLUSIONS

Given the importance that the motor abilities have in the system of selecting, training, and educating police personnel, as well as in the control of their development, there appears to be a constant need for new models and improved curricula for their training and development, as well as for checking the achieved levels of general and specific motor abilities (Anderson et al., 2001; Dopsaj i sar., 2007). The results of this research lead to the conclusion that the instruction in Special Physical Education at the ACPS should in future focus more intensely on developing the maximal isometric force.

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THE INFLUENCE OF DIRECT PRE-ACTIVATION ON THE STARTING PERFORMANCE OF ELITE SKI CROSS ATHLETES

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INTRODUCTION

Ski Cross combines alpine ski racing with jumps, banked turns and other obstacles as 4-6 athletes compete head-to-head mode on one track. In Ski Cross the start has been shown to be a key performance indicator, but there is limited information about power variables that influence the start (Arguelles et al., 2011). A major objective of sport scientists working with high performance athletes is to optimize training and testing methods. A start tool has been developed to optimize the start performance of world class athletes (Raschner et al., 2009). There is no published scientific work examining start performance in Ski Cross.

The aim of this study was to evaluate the influence of muscle pre-activation on start time in elite ski cross racers.

METHODS

In cooperation with the Austrian National Ski Cross Team, two female (age 21.5 ± 0.7years, height 165.5 ± 5.7cm, mass 64.9 ± 0.1kg) and eight male (age 22.9 ± 3.2years, height 181.6 ± 6.2cm, mass 85.1 ± 7.7kg) elite athletes participated in this study. A self-designed ski cross-start was constructed on a grass slope to investigate starting performance. Wet mats guaranteed sliding of skis. Athletes performed a 15 minute individual warm up session and then performed 3 different type of starts in a random order (start with pre-activation, start without pre-activation and a start where the athletes performed their normal technique). Each start technique the athlete had to absolve three times in a row.

Overall start time was measured using timing lights (Brower) set at the start handles and at 8.5m from the starting gate. Four U2B force transducers (Hottinger Baldwin Messtechnik, Germany) with strain-gauge technology were connected to the start handles to allow force measurements on horizontal and vertical side. All collected data were displayed by LabView program and were investigated using analysis of variance with significance set at $p < 0.05$.

Figure 1: Self-designed ski cross start testing tool

RESULTS

Start time during the push-off phase with muscle pre-activation (p = 0,000) and following the individual preferred start technique (p = 0,006) was significantly faster than without muscle pre-activation. Overall start time was also significantly faster with muscle pre-activation (p = 0,001) and following the individual start performance (p = 0,018) compared to no muscle pre-activation. The time difference from the opening of the gate to the last contact of the athlete at the handles showed significantly differences with muscle pre-activation and the individual start performance (p = 0,000) compared to no muscle pre-activation. The time an athlete needs to reach his maximum force after the gate opens also diverse between muscle pre-activation (p = 0,024) and the athlete's normal technique (p = 0,083) in comparison to the starts with no pre-activation. The analyses of horizontal and vertical force development reflected differences within the three conditions. Without any pre-activation the athletes gained a maximum force in horizontal direction of 985N, with muscle pre-activation 1043N (p = 0,023) and with their individual best starting technique 1075N (p = 0,043). In vertical direction the differences were also significantly. With their individual preferred start technique (p = 0,001) followed by the starts with muscle pre-activation (p = 0,005) the athletes were stronger than without muscle pre-activation.

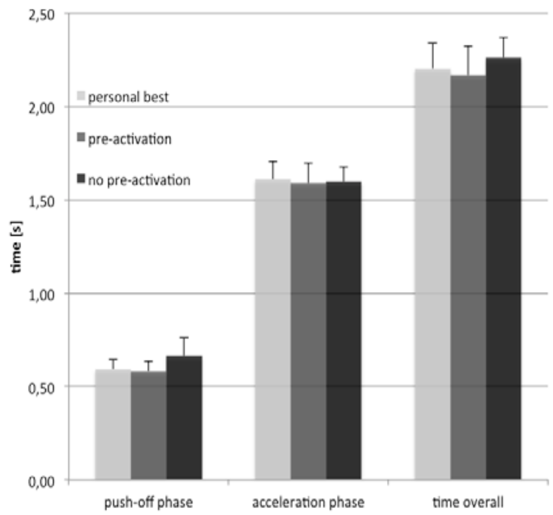

Figure 2: Different periods during SX - Start

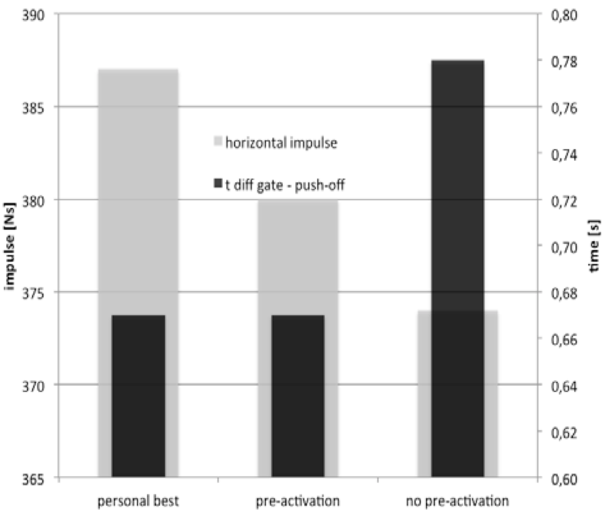

Figure 3: Correlation between impulse and push-off time

DISCUSSION

This study provides evidence that muscle pre-activation immediately before opening of the start gate is crucial for maximum acceleration at the start. Force measurement analysis suggests that a high impulse developed quickly is a determining factor for optimal starting performance. As the study shows it is important for the athlete to prepare himself in an optimal starting position before the gate opens. He has to bring a high percentage of his maximum force on the handles to develop his fastest starting movement. Because of the very short time frame between the starting command and the opening of the gate it is difficult and not proved, that a postactivation potentiation (Sale, 2002) in this specific situation has any influences on the start.

The principle of a start force could be a possible explanation to achieve an optimal starting performance. Even there the athlete has no chance to do any strike out movement before the push-off and so his only alternative is to do a deliberately pre-activate immediately before opening of the start gate.

Additional pole pushes and skating strides are important to accelerate after the gate opens. These techniques must be optimized to take and control the lead at the first section after the start.

CONCLUSIONS

The main conclusion of this study is that muscle pre-activation significantly improves ski cross starts. These results cannot be generalised for all ski cross starts on snow due to the small subject sample size and the non-snow surface utilised. Further research is needed to examine starts in sport-specific conditions such as on snow and during competitions. Additionally analysis to find the optimal time frame regarding the postactivation potentiation could help athletes and coaches to perform better.

During a ski cross-specific conditioning training it is important to improve maximum force and speed. Elite athletes in seasonal sports must have the possibility to include an optimised training- and testing tool in their training programs to practice their starting performance.

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THE IMPACT OF EXPERIENCE ON THE USE OF ADVANCED COACHING TECHNIQUES

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INTRODUCTION

A well-designed pre-activity warm-up will bring about various physiological changes that will enhance training activity or competition. Recent research indicates that alternative warm-up methods have the ability to bolster an athlete's strength/power potential. The usage of post activation potentiation (PAP) to improve athletic strength has recently generated interest within the strength and conditioning community [3]. Studies have shown that the ability to develop force can be improved for a short period following repeated maximal strength exercise. PAP takes advantage of the contractile history of a muscle to influence the mechanical performance of subsequent muscle contractions. Fatiguing muscle contractions impair muscle performance; whereas, non-fatiguing muscle contractions, typically at high loads of brief duration, may enhance muscle performance [3]. Thus, PAP results in increased muscle force and rate of force development as a result of previous activation of muscle. The large monetary investment made to hire competent coaches should ensure employment of knowledgeable professionals that utilize evidence-based practices like PAP. However, the numbers of coaches who utilize evidence-based practices that are grounded in peer reviewed research are unknown. The purpose of this study is to elucidate the types of practices utilized by certified United States of America Track and Field (USATF) coaches with respect to the use of advanced coaching techniques like post-activation potentiation (PAP).

METHODS

A total of 254 track and field coaches (Age: 33.4yrs±9.7; Male 75.9%, Female 24.1%; Currently Coaching: Youth 8.3%, HS 41.1%, College 44.3%, post Collegiate/Masters 4.0%) who were in attendance at the summer Level II/Level I USATF school completed the survey. Data were analyzed for differences in reported use of PAP by using overweight implements via Pearson's $\chi 2$ analysis.

RESULTS

Coaching experience was significantly related to the use of PAP and heavy shot puts as part of the competition warm-up ($\chi 2 = 8.709$, $p=0.035$, $n=62$). Coaches with the least experience (1-5yrs) reported the highest level of use of heavy implements during competitive warm-up (69.7%, n=23). Competitive experience in one of the throwing events was also related to reported use of PAP in practice ($\chi 2=7.119$, $p=0.009$, $n= 62$) and in pre-competition warm-up ($\chi 2= 15.406$, $p<0.001$, $n= 62$) for the shot put event.

DISCUSSION

A good coach must weigh the costs and benefits of training and exercise regimens to make informed decisions about the best approach for each athlete. The results of this study suggest that coaching and competitive experience has an impact on the type of advanced techniques employed by coaches. Previous research suggests there are several sources that enhance the chances of being a successful coach. Carter and Bloom [1] suggest that previous athletic experience in the specific sport coached increases the likelihood that he/she will be a successful coach for that sport. Moreover, a coach is more likely to succeed at a level that he/she has competed. Prior coaching experience, either at a lower level or through a mentorship, has also been shown to enhance the probability of being successful [2]. Usually, coaches tend to advance as they achieve success at their current level (i.e. lower level institutions to elite level institutions) or attain the position of head coach after serving as an assistant coach. In addition to previous athletic experience and prior coaching experience, coaching knowledge and competence increases the chance of success [1]. This apparent disconnect between the training coaches receive via certification and the on-field practices they employ is a concern that needs to be addressed.

CONCLUSION

Playing experience and coaching experience has an impact on the use of advanced techniques like PAP. The reasons for this disconnect between science and practice for the more experienced coaches is unclear, but coaches are creatures of habit and sometimes become entrenched in traditional dogmatic practices.

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EFFECTS OF MUSCLE STRENGTH POTENTIATION BY CONTRALATERAL EXCITATION

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INTRODUCTION

Effects of enhanced of muscle function following a high force activity - postactivation potentiation - are well known [1,2,3]. They can be observed equally as a result of voluntary muscle contraction [2] and direct stimulation [3]. These effects are attributed to improvement of sensitivity to calcium [1,2,3]. However, there is no literature on how these effects manifest themselves on the level of the central nervous system. Yet, they can be evaluated by means of simultaneous registration of mechanic activity of same groups of muscles on both extremities. Purpose of our investigation was studying the effects of maximal isometric contraction of varying duration performed by muscles of one leg on maximal voluntary strength of similar muscles of the contralateral extremity.

METHODS

The investigation was performed with participation of 12 physically active young men who had signed the informed consent for the experiment. The test-subjects made the conditioning maximal isometric contraction of the right knee extensors over 5, 10, 30 and 60 seconds; before and in a second after this exercise they performed maximal voluntary contraction of knee extensors of both legs. Torques were registered using strength measurement device BIODEX System 3 Pro outfitted with two dynamometry heads (fig. 1). All testing and workout attempts were fulfilled in the isometric regimen with the optimal knee angle of 100 degrees.

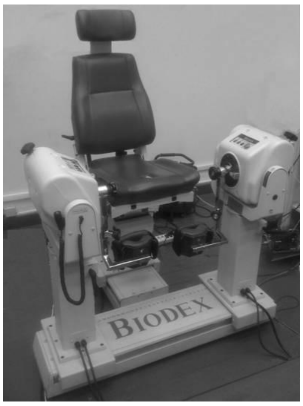

Fig. 1. Strength measurement device BIODEX System 3 Pro outfitted with two dynamometry heads

RESULTS

It was shown that the conditioning contraction reduces maximal strength of the right knee extensors, whereas strength of the contralateral muscles either does not change or makes an increase. Following a 10-second maximal conditioning contraction this cross-gain made up 8±1.2% on the average of the group of test-subjects.

DISCUSSION

The experiment was arranged so that to cancel any influence of peripheral factors on muscle strength potentiation. The conditioning contraction was fulfilled by one leg, while the potentiation effect was evaluated in the other. This means that the effect can be initiated by the central nervous system only: excitation of central structures and ensuing excitation transmission onto the contralateral nervous centers.

The maximal effect was observed after the 10-s long conditioning contraction. As for the other periods of contraction, their effect was small (6.7 % after 30-s contraction), if any (after 5- and 60-s contractions). Absence of the effect from the short conditioning contraction can be associated with insufficient period of excitation. Absence of the effect in the event of contraction extended to 60 s can be explained by developing central fatigue.

CONCLUSIONS

In summary, strength potentiation in a muscle group can be achieved through maximal contraction of the contralateral group of muscles.

Optimal duration of conditioning contraction should be approximately 10 seconds.

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DEVELOPMENT OF A MULTI-AXIAL MECHATRONIC TRAINING AND TESTING DEVICE FOR HIGH PERFOMANCE SKI RACERS

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INTRODUCTION

Alpine ski racing is a very popular winter sport. It is generally accepted that ski racers must possess excellent physical fitness in order to cope with the demands that are placed upon the musculoskeletal system (Turnbull et al. 2009). Strength and power are very important in ski racing so high quality training and testing of these qualities is imperative (Patterson et al. 2009). The quality of strength training can be improved by using technique-specific exercises therefore ski specific training devices should be available (Müller et al. 2000). High performance athletes in seasonal sports must have conditioning programs that include sport-specific technical aspects (Raschner et al. 1997). Mechatronic systems utilizing mechanical, electrical, electronic and software components are commonplace in industry. Published documentation of robotic applications in sport science is rare, with the exception of isokinetic devices (Haddadina et al. 2009).
The aim of this project was to develop a multi-axial mechatronic-based leg strength training and testing device for high performance ski racers.

METHODS

The following conditions in the development of the new training and testing device must be met: linear and curvilinear movements, variable speeds, bilateral and unilateral training, concentric and eccentric training, active or passive training and ski-specific training. The athlete should have force and position visual feedback and a test mode should be available for all movements. The im-evolution is constructed as a right/left leg independent system, each consisting of two synchronized servomotors for the horizontal and vertical plane (Bosch-Rexroth) connected to toothed drive belts and servo controllers (KEBA). The device operates with a programmable logic controller (PLC) used for automation of electromechanical input and output processes. Training and testing programs are written on a personal computer and then downloaded onto the PLC. The coach operates the im-evolution with a handheld terminal with a 6.5” VGA TFT display (KEBA). A button on the handheld terminal must be activated in order for the system to function, and the servomotors will automatically stop if the button is released or pressed too hard.

RESULTS

The introduced prototype (see figure 1) allows for both single axis (horizontal and vertical linear movement) and for two coordinated axes (curves, circles and ellipses) active and passive training and testing. All movements can be performed unilaterally or bilaterally with variable ankle/knee/hip joint angles. The maximum speeds of horizontal and vertical movements are 2.5m/s and 3.3m/s, respectively. Maximum load capacities are 4.8kN horizontally and 1.6kN vertically. Power values of the IM-evolution compared to a load cell confirmed the accuracy of the mechatronic components in both planes. The form of the ellipse (steeper or flatter angle of the ellipse) or circle as well as the repetitions per minute (up to 100) can be chosen on the handheld control (see figure 2).

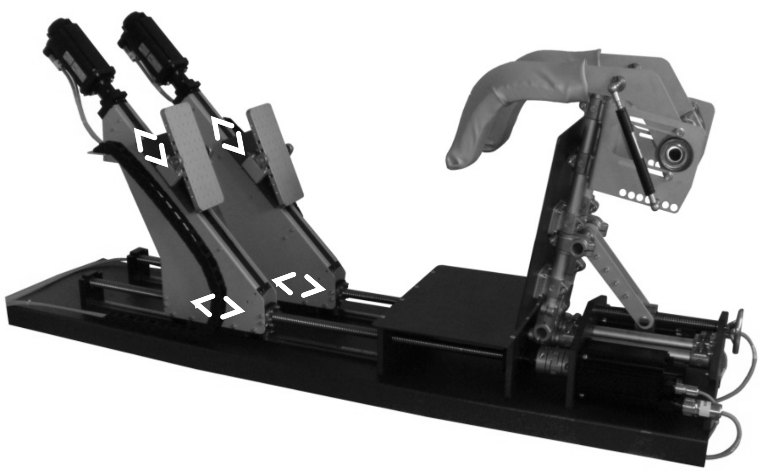

Figure 1: Prototype of im-evolution

If one wants to train ski-specific aspects, several stretch shortening cycles or stochastic shocks can be included. Another ski-specific aspect is a displaced outside leg during an ellipse motion. With every rotation the displacement will change to simulate turns. Regardless of training and testing, target force and position values of the horizontal and vertical axes can be automatically recorded.

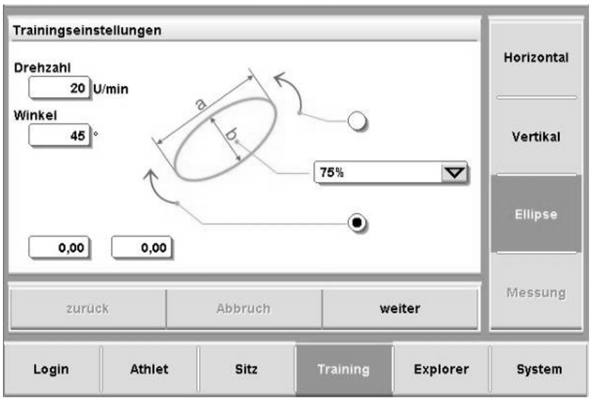

Figure 2: Handheld display for ellipse adjustment

DISCUSSION

The im-evolution utilizes mechatronics allowing a multitude of ski-specific combinations of concentric and eccentric exercises. Presently robotic training devices are primarily used to treat individuals with a locomotor dysfunction. They have been widely developed for gait rehabilitation of post-stroke patients (Jia-fan et al. 2010, Bolliger et al. 2008). From our knowledge only Al-Bahadly et al. (2009) presented the development of a robotic training platform for use in martial arts and boxing. This training apparatus has two movable arms, each with rotating wrists that can move side-to-side. It is intended to emulate the pad-holding trainer integrating modern robotics technology into the training process. A measurement and feedback training tool which is driven by two synchronised servo motors was published by Lembert et al. (2011) to improve the arm strokes of high-performance luge athletes. LaStayo et al. (2000) introduced an eccentric bike as an efficient training tool with high potential for clinical implications to increase muscle strength. A modified version was successfully implemented from Hoppeler & Vogt (2009) in the training process of alpine ski racers.

Specific hamstring training on the im-evolution including stochastic shocks in the vertical plane or with curves could have potential for injury prevention for ski racers. The pressure on athletes to return to competition following injuries demands a rapid reintegration into the training process. Specifically, sport science in collaboration with medical consultation is called upon more than ever to give insights for an optimization of training methods during injury rehabilitation. According to respective load capacity and rehabilitation state of the athlete, resistance, movement velocities and motion amplitudes can be individually adjusted with the im-evolution.

CONCLUSIONS

General training and testing on the im-evolution offer basic research opportunities such as the analysis of the horizontal versus vertical forces or the implementation of the stretch-shortening cycles in different training modes. The im-evolution allows a multitude of ski-specific combinations of concentric and eccentric exercises for leg/hip extension and flexion muscles. Mechatronics can transform sport-specific training conceptions into reality for high performance athletes.

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DOES TRAINING WITH ELASTIC RUBBER BAND SUPPORTED EXERCISES FACILITATE IMPROVEMENTS IN PERFORMANCE AND MUSCULAR ADAPTIONS IN HIGH LEVEL POWERLIFTERS?

Lars Edvin Samnøy[1,2], Alexander Kirketeig[2], Dietmar Wolf[2], Olivier Seynnes[1], Gøran Paulsen[1] and Truls Raastad[1].

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INTRODUCTION

Training with support from Elastic Rubber Bands (ERB) is a common training commodity in the Powerlifting community, popularized in the USA in the 1990s by Louie Simmons at Westside Barbell club. When connected to the bar from a power rack the support from the rubber bands mimic the effects of the suits used in powerlifting competitions (International Powerlifting Federation, IPF). The tightly fitted suits contribute greatly to the performance of the powerlifters by supporting elastic properties. The greatest contribution occurs in the biomechanically least efficient positions for the muscles to generate force, i.e. the bottom position in the squat (Nissell et al.1986), at the chest level in the bench press (Ariel. 1976) and during knee pass in the deadlift (Escamilla et al. 2000). Consequently, training the three powerlifting exercises with the support of ERB may be closer to the actual competition lifts than performing the same exercise without any supporting equipment. Furthermore, training with ERB-support might lead to more specific adaptations at the muscular level which in turn may lead to better in-competition performance in Squat with equipment (SQEQ) and deadlift with equipment (DLEQ).

Therefore, the hypothesis of the current study was that training with ERB-support would lead to specific muscular adaptations, as reflected by changes in muscle architecture. Furthermore, these specific adaptations would in turn lead to improved performance in Squat (SQ) and Deadlift (DL) performed with IPF approved suits.

METHODS

Twenty-four powerlifters volunteered to participate in the study (20 males and 4 females). Four lifters did not complete the study. Top national athletes from the Norwegian powerlifting federation were included in the study. The included lifters were randomly assigned to either the rubber band supported training group (RBTG) or to the normal unsupported training group (NUTG) from pairs of ranked lifters (RBTG group: n = 12, age = 20.6 ± 2.5 BW = 100.3 ± 28.0, NUTG: n = 12, age = 23.6 ± 6.5, BW = 97.9 ± 27.4). The subjects completed tests before and after an 8-week training intervention as well as a powerlifting competition with equipment after 10-weeks. The RBTG completed all training in the SQ and DL with rubber bands supporting the bar from top of a power rack. The effect of ERB supported training in bench press was not evaluated in this study due to the fact that the lifters already had years of experience with bench press training with rubber bands or similar supportive devices. 1RM tests (without equipment) in SQ and DL were tested in both groups before and after 8 weeks of training, with and without rubber bands on the same day. Training loads (kg) for the 8-weeks intervention was determined from 1RM with rubber bands in the RBTG and 1RM without rubber bands for the NUTG. All subjects performed SQ and DL training 4-days a week, and they followed the same training program (sets x reps). Other outcome variables included maximal isokinetic and isometric knee-extension torque, MRI scan of thigh muscles, and ultrasound scan of the m. vastus lateralis to check for possible changes in muscle architecture. The 1RM tests in competition after 10 weeks of training were done wearing suits. Results from this competition were compared with the latest competition results recorded for each individual lifter.

RESULTS

Both groups increased 1 RM performance in squat and rubber band supported squat by 4% ($p<0.05$), while no change was observed in competition result in the squat exercise (figure 1). In deadlift, the RBT-group increased the rubber band supported 1 RM and competition performance by 5% and 3%

respectively (p<0.05). A tendency towards improvement (p<0.10) was seen in the NUT-group. No group differences were found.

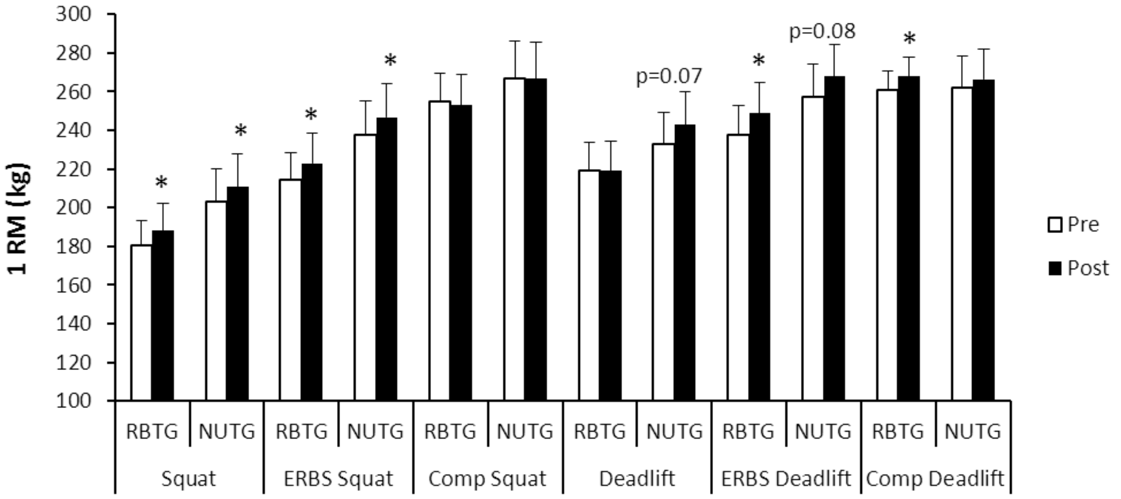

Figure 1. 1 RM results in squat and deadlift before and after the 8 weeks for the "Rubber band supported training group (RBTG) and the "Normal unsupported training group (NUTG), 1 RM results Comp Squat and deadlift after 10 weeks. ERBS squat = elastic rubber band supported squat, ERBS deadlift = elastic rubber band supported deadlift, Comp squat = Squat with equipment, Comp Deadlift = Deadlift with equipment).

No significant changes were observed in muscle architecture (thickness, pennation angle and fascicle length), or in cross sectional area of the thigh muscles, in any group.

DISCUSSION

In this study the RBT-group performed all SQ and DL training with the bar attached to elastic rubber bands hanging from the top of a power rack. The elastic bands unloaded the bar substantially, in the distal portion of the lifts (25-30%, 34-55 kg) with gradually less unloading near full extension of the lifts. Only the RBT-group reached statistically significant improvement in the DLEQ. However, neither group improved their result significantly in the SQEQ. This might be explained by the difference in technical difficulty between the SQEQ and DLEQ, with SQEQ being far more technically difficult to perform. Performance improvements in the SQEQ likely require a larger training volume and more frequent training with equipment than what was performed in this period (only 1% of the total training volume was done with equipment in both groups). An eight week training period is likely to be too short to induce significant changes in muscle size and architecture in highly trained powerlifters.

CONCLUSION

The results indicate that training with Elastic Rubber bands may be beneficial for high level Powerlifters as a valuable training tool to improve competition performance in the deadlift with equipment. However, in the squat exercise no detectable advantages were seen for competition performance when comparing training with or without supportive rubber bands for 10 weeks.

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POSTER WITH DEFENSE 2

Friday Oct. 26th,
14:30 – 16:30
(Sports Hall)

The poster session starts at 14:30 pm. Each presenters are given 5 minutes for presentation, including question and answers. The Chair person leads the session and presenters will present in order 1 to 12.

Poster 1
Colleen Deane
Testosterone rescues differentiation and hypertrophy in artificially aged skeletal muscle myoblasts

Poster 2
Paulo Gago
Passive muscle length changes affects twitch potentiation in power athletes

Poster 3
Yuta Hasegawa
Time course changes in anaerobic power during daily 2 week sprint training followed by short-term detraining.

Poster 4
Kristoffer T. Cumming
Acute effects of resistance exercise with blood flow restriction on HSP27 and αB-crystallin response in human skeletal muscle

Poster 5
Boris Jiovtseff
1RM prediction and load-velocity relationship

Poster 6
Christian Helland
Differences in mechanical and material properties of the patellar tendon in healthy athletes vs. athletes with patellar tendinopathy

Poster 7
Thue Kvorning
Eight weeks of strength training enhances the number of myonuclei in type ii fibers, but this is blocked with suppressed testosterone levels

Poster 8
Martin Lemke
Dorsiflexor strenght curves of young and older adults

Poster 9
Fernando Pareja
Acute metabolic and mechanical response to resistance training performed at maximal intended vs. half-maximal lifting velocity in the bench press exercise

Poster 10
Carson Patterson
Development of a multi-axial mechatronic training and testing device for high perfomance ski racers

Poster 11
Sven Zeißler
Effects of a six-months strength training combined with rehabilitation sports for internal diseases (tertiary prevention) on type 2 diabetics

Poster 12
Wiig, Håvard
Effect of bicarbonate supplementation on male top-level rowers

TESTOSTERONE RESCUES DIFFERENTIATION AND HYPERTROPHY IN ARTFICIALLY AGED SKELETAL MUSCLE MYOBLASTS

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INTRODUCTION

Resistance exercise acutely elevates endogenous levels of circulating testosterone (Ratamess et al. 2005), eliciting an anabolic effect, and leading to increases in muscle strength and fibre hypertrophy (Ahtiainen et al. 2011). However, with age, there is a gradual decline in serum testosterone levels, which correlates to wasting of skeletal muscle (sarcopenia) (Morales et al, 2010). Sarcopenia contributes to a reduction in muscle size, strength and lower regenerative potential (Serra et al. 2012). The molecular mechanisms by which testosterone (T) contributes to skeletal muscle growth and regeneration remain poorly understood. Therefore, we investigated the effects of T on its ability to restore differentiation in skeletal muscle cells that had undergone multiple population doublings (MPD) and exhibit a degenerative ageing phenotype and reduced differentiation vs. parental controls (CON) (Sharples et al. 2011).

METHODS

Monolayer cultures, of mouse C2C12 skeletal muscle cells with no population doublings (CON) were compared with cells that had undergone multiple population doublings (MPD (58 doublings)). Cells were exposed to a standard low serum conditions and treatment consisted of a vehicle control (DMSO) or testosterone treatment (100 nM) for 72 hrs and 7 days (early and late muscle differentiation respectively). For both time points, morphological analyses were performed to determine myotube width (µm) and myonuclear accretion as indices of myotube hypertrophy. Changes in gene expression for myogenin (marker of differentiation) and myostatin (negative regulator of hypertrophy) were also conducted. The experiment was performed in triplicate.

RESULTS

Myotube width in CON cells increased from 17.32 ± 2.56 µm to 21.02 ± 1.89µm ($p<0.05$) after T exposure. MPD cells also improved their myotube width after T treatment from 14.58 ± 2.66µm to 18.29 ± 3.08µm ($p<0.05$). Indeed, MPD cells responded with a similar increase (+25%) in myotube width to CON cells (+21%) suggesting a similar ability to respond to the exogenous T administration. With 7 days exposure, T treatment increased the percentage of myotubes expressing 5+ nuclei in both CON cells (+30%) and MPD cells (+30%). After 72 hrs, myogenin mRNA expression significantly increased in both cell types when T was administered compared to non-treated controls ($p<0.05$). The expression of myostatin mRNA after 7 days was significantly reduced in MPD T-treated cells ($p<0.05$), yet remained unchanged in the CON cells.

DISCUSSION

The present study supports testosterone's role in myogenic differentiation but more importantly, shows the capacity to rescue differentiation in artificially aged/degenerative skeletal muscle myoblasts. The administration of T, may further enhance hypertrophy through the inhibition of myostatin (Braga et al. 2012), as observed in the current study after 7 days exposure. Interestingly, the extent of the increases in myotube width with a T-stimulus were similar in magnitude between CON and MPD, highlighting that perhaps between "young" and "old", the regenerative potential in skeletal muscle cells may remain the same.

CONCLUSIONS

This study provides initial data to further elucidate the mechanism of action of T in muscle wasting with age.

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PASSIVE MUSCLE LENGTH CHANGES AFFECTS TWITCH POTENTIATION IN POWER ATHLETES

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INTRODUCTION

Post activation potentiation (PAP), i.e. the acute enhancement of muscle contractile properties after a maximal voluntary muscle action (MVC), is a widely accepted physiological phenomenon. Peak twitch (PT), rate of torque development (RTD) and rate of torque relaxation (RTR) are typically increased up to 10 minutes after MVC (1). Though many have speculated that these enhancements may be beneficial for sports performance, its effects on contractile properties in dynamic muscle actions where muscles undergo length changes are poorly understood (2, 3). Therefore, the aim of the current study was to investigate PAP of plantar flexor twitches and its recovery in different muscle action types and angular velocities in power athletes.

METHODS

Plantar flexor twitches were evoked in 11 high level power athletes using supra-maximal electrical stimulation of the tibial nerve, during isometric and dynamic (lengthening and shortening) passive foot movements at different angular velocities (30 and $60^{\circ}\cdot s^{-1}$). Twitches were evoked with the foot at or moving through an ankle angle of 90˚ before and at 5, 30, 60, 120, 180, 240, 300 and 600 s after a conditioning 6-s isometric MVC. PT, maximal RTD and maximal RTR were measured from each twitch. Changes in twitch properties were evaluated using repeated measures ANOVAs followed by Tukey post hoc tests. Significant differences were reported if $p<0.05$.

RESULTS

The conditioning MVC acutely enhanced twitch contractile properties (PT, RTD and RTR) in all length change conditions, but to a different degree and for a different duration (Table 1). 5s after the conditioning MVC, PT was enhanced 4 times as much in fast shortening (118±35%) as compared to fast lengthening (30±13%) with differences diminishing over time. RTD and RTR were also greater in shortening as compared to lengthening, ranging from 108±35% to 63±21% and from 100±37% to 52±30% for RTD and RTR, respectively. After 5 s PAP was also modulated with length change velocity in lengthening for PT and in shortening for RTR (◊ in Table 1). PT was significantly enhanced for a mean time of 4.2±0.4 minutes, RTD for 2.8±0.8 and RTR for 2.6±1.3. The duration of potentiation was not consistently related to ongoing muscle length changes.

DISCUSSION

Our study presented higher PAP levels in shortening when compared to lengthening, supporting the findings in (2) as well as the muscle lattice spacing theory and Huxley cross bridge kinetics models (4). The present study is the first to provide data on potentiation and its recovery in evoked twitches during ongoing muscle length changes of highly trained athletes. Substantial potentiation occurred in fast lengthening (30±13% 5s after MIVC) rejecting the idea that the PAP might be insignificant (3) or minute (2) in lengthening.

Table 1: Non normalized values for Peak twitch (PT), Rate of torque Development (RTD) and Rate of torque Relaxation (RTR) before (con) and at different times after the conditioning MIVC. Values marked with (*) indicate significant potentiation compared to control values within the same length change condition ($p<0.05$). Differences in degree of potentiation (%) are indicated with an(ǂ)for differences between fast lengthening (LENfast) and fast shortening (SHOfast); an (♣) for differences between slow lengthening (LENslow) and slow shortening (SHOslow); an (§)for differences between isometric and all dynamic modes and with an (◊)for differences between velocities within the same action type.

			PT		
	LENslow	**LENfast**	**ISO**	**SHOslow**	**SHOfast**
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Con	32,3 ± 5,3	36,3 ± 6,3	23,3 ± 2,2	13,6 ± 1,8	10,7 ± 1,3
5	45,8 ± 6,7*♣§ ◊	47,0 ± 8,0*ǂ§◊	38,7 ± 4,3*§	28,6 ± 4,0* ♣§	23,2 ± 3,4*ǂ§
30	39,7 ± 5,4*♣§	41,4 ± 6,2*ǂ§	32,9 ± 2,7*§	22,9 ± 3,1* ♣§	19,0 ± 2,1*ǂ§
60	36,3 ± 4,9*♣§	39,0 ± 6,0*ǂ§	29,1 ± 1,7*§	18,6 ± 2,4* ♣§	15,3 ± 1,6*ǂ§
120	35,4 ± 4,9*♣	39,3 ± 6,4*ǂ§	27,6 ± 1,6*§	16,4 ± 1,7* ♣	13,1 ± 1,4*ǂ
180	34,9 ± 5,1*	38,9 ± 6,6*	26,5 ± 1,8*	15,3 ± 1,9*	12,3 ± 1,2*
240	34,4 ± 5,5*	38,3 ± 6,8*	26,0 ± 2,0*	14,9 ± 2,0*	12,1 ± 1,3*
300	33,4 ± 5,4	37,4 ± 6,2	25,8 ± 1,9*	14,8 ± 1,9	11,7 ± 1,2
600	31,3 ± 5,2	36,1 ± 6,2	23,8 ± 2,0	13,1 ± 2,1	10,4 ± 1,3
			RTD		
Con	302,1 ± 39,1	330,7 ± 48,3	231,6 ± 30,5	183,5 ± 25,4	177,6 ± 26,8
5	516,2 ± 72,8* ♣§	535,8 ± 87,0*ǂ§	464,0 ± 67,1*§	377,5 ± 54,3* ♣	345,9 ± 52,4*ǂ
30	449,6 ± 63,4* ♣§	468,8 ± 68,9*ǂ§	394,5 ± 48,4*§	313,6 ± 41,0* ♣	299,2 ± 39,9*ǂ
60	368,9 ± 56,2* ♣§	402,5 ± 60,5*ǂ§	317,9 ± 43,2*§	262,4 ± 35,0* ♣	251,6 ± 37,6*ǂ
120	334,2 ± 39,3* ♣	373,8 ± 50,1*	274,3 ± 26,3*	230,0 ± 25,2* ♣	213,6 ± 25,9*
180	317,1 ± 40,2 ♣	360,5 ± 49,4*	251,1 ± 18,0	214,4 ± 28,6* ♣	201,4 ± 22,7*
240	309,0 ± 40,5	355,8 ± 47,1*	249,2 ± 18,7	200,7 ± 32,4	198,3 ± 25,1
300	307,2 ± 39,4	347,6 ± 44,7	248,3 ± 20,5	205,2 ± 24,9	193,2 ± 24,8
600	295,6 ± 39,7	332,3 ± 42,6	243,2 ± 23,3	178,2 ± 32,0	173,2 ± 26,0
			RTR		
Con	-144,7 ± 26,6	-124,9 ± 25,8	-132,7 ± 14,1	-85,9 ± 11,4	-94,3 ± 15,2
5	-217,7 ± 34,1* ♣§	-186,7 ± 33,9*ǂ§	-219,9 ± 26,3*§	-169,7 ± 27,6*♣§◊	-166,5 ± 28,3*ǂ◊
30	-182,0 ± 25,6* ♣§	-153,8 ± 25,5*ǂ§	-185,2 ± 13,5*§	-136,4 ± 19,0* ♣§	-141,7 ± 18,5*ǂ
60	-162,9 ± 25,9* ♣	-137,7 ± 24,0*ǂ§	-165,4 ± 12,6*§	-116,9 ± 14,0* ♣	-118,2 ± 16,5*ǂ
120	-161,3 ± 28,0*	-140,4 ± 23,6*	-155,5 ± 12,5*	-101,8 ± 10,9*	-103,6 ± 12,6
180	-155,8 ± 32,4	-139,9 ± 25,8*	-149,8 ± 14,4*	-95,9 ± 11,4	-99,1 ± 12,0
240	-153,7 ± 29,2	-138,0 ± 25,8*	-147,6 ± 15,4*	-93,3 ± 13,7	-98,3 ± 12,1
300	-152,2 ± 28,8	-133,9 ± 23,9	-144,4 ± 13,2	-94,6 ± 13,5	-96,7 ± 12,9
600	-143,7 ± 23,2	-125,2 ± 22,7	-135,5 ± 13,8	-83,1 ± 14,9	-90,3 ± 14,7

CONCLUSION

We conclude that in power trained athletes potentiation of twitch contractile properties is higher than previously reported for active subjects. Potentiation levels are affected by ongoing muscular length changes up to 4 minutes after MVC. The results suggest that a conditioning MVC can facilitate muscle properties relevant for enhancing dynamic muscle strength, rate of torque development and relaxation in functional and sport performance tasks. However associations between dynamic twitch potentiation and functional tasks requiring explosive dynamic torque development, need further investigation.

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TIME COURSE CHANGES IN ANAEROBIC POWER DURING DAILY 2 WEEK SPRINT TRAINING FOLLOWED BY SHORT-TERM DETRAINING.

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INTRODUCTION

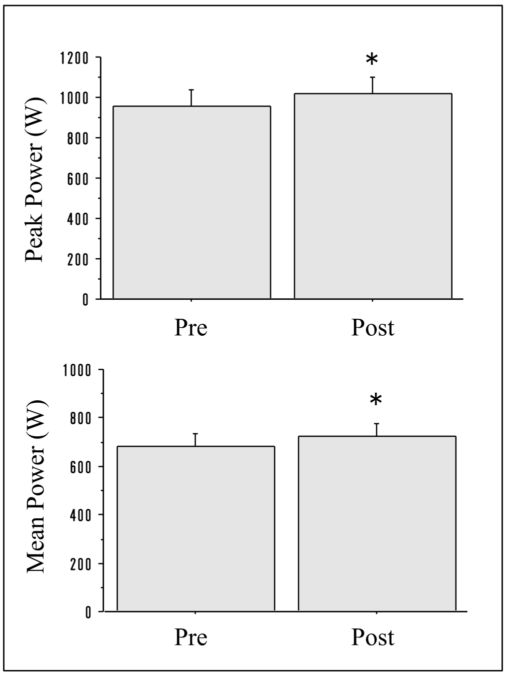
Adaptation to sprint training is dependent on the duration of exercise, recovery between repetitions, total volume and frequency of training bouts [1]. Significant increases in resting PCr level and the activities of creatine kinase, pyruvate kinase and lactate dehydrogenase have been shown by 14 sessions of daily high-intensity sprint training [2]. The result indicates that consecutive exercise training during short period produces larger increase in glycolic system related enzyme activities and intramuscular PCr level. However, in Parra's study [2], sprint performance did not improve in post training performance test, took place 48h after the last training session. This suggests that 48h of rest period after the last training session was insufficient to recover from the accumulated fatigue of daily training. We hypothesized that consecutive exercise training during short period would enhance sprint performance dramatically when longer rest period was provided following the last session of the consecutive exercise training. Therefore, the purpose of the present study is to investigate the time course changes in anaerobic power during 12 sessions of daily sprint training followed by a week of detraining period.

METHODS

Seven physically active men [age 22.7 (mean) ±0.2 (SE) yrs, height 175.6 ± 1.7 cm, body mass 81.3 ± 8.3 kg] participated in this study. They performed 12 sessions of sprint training on cycle ergometer every day. The sprint training program consisted of 2-4 sets of 30 sec maximal pedaling. The number of the set was progressively increased every 4 sessions from 2 to 4 sets. The resistance for the first set was set at 7.5% of bodyweight and it was reduced to 5.0% for the second set or more. During each training session, the subjects were verbally encouraged and instructed to give their maximal effort. After 12 days of daily training, the subjects spent 7 days of detraining period. Post-training test was carried out immediately after the 7days detraining period. A 30sec maximal pedaling test at 7.5% bodyweight was conducted to determine peak power output and average power output before and after the training period. Sprint performance was also recorded during the first set of daily training to monitor time course changes throughout the training period.

RESULTS

As a result of 12 sessions of daily sprint training, significant increases in peak power (6.5%) and mean power (10.5%) were observed ($P < 0.05$, Fig.1). When relative change (vs. pre-test) in peak power output was calculated, a significant increase was found at day 11 and post-test ($p < 0.05$, Fig. 2). However, there was no significant improvement in relative change of mean power.



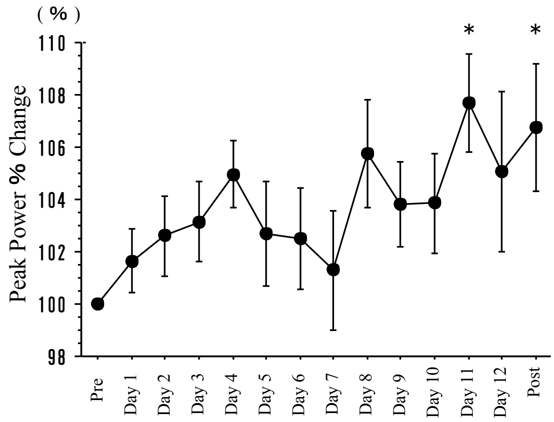


Fig.1 (left) Peak power output and mean power output, before and after the training period during 30s maximal pedaling test. * ; p<0.05 vs. pre. Values are mean ± SE.

Fig.2 (above) Time course change in peak power output. * ; p<0.05 vs. pre. Values are mean ± SE.

DISCUSSION

As expected, peak and mean power output during 30s maximal sprinting significantly increased after the training period. In contrast, previous study using 14 days successive training sessions [2] failed to improve sprint performance, despite the large increase in resting PCr level and enzyme activities, probably because of insufficient recovery from accumulated fatigue. Based on this finding, the present study was designed to set 7 days detraining (recovery) period following the 12 days successive sprint training. Consequently, a significant increase in power output was found after the detraining period, suggesting that subjects succeeded to recover from accumulated fatigue.

CONCLUSIONS

In conclusion, power output of supramaximal pedaling test improved by 12sessions of daily training followed by a week of detraining period. It is possible that supercompensation is involved in improvement of sprint performance following short-term detraining period.

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ACUTE EFFECTS OF RESISTANCE EXERCISE WITH BLOOD FLOW RESTRICTION ON HSP27 AND αB-CRYSTALLIN RESPONSE IN HUMAN SKELETAL MUSCLE.

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INTRODUCTION

Low load strength training with blood flow restriction (BFR) has gained interest in recent years because it has been shown to increase strength and induce muscle hypertrophy to a similar extent as conventional heavy load strength training (6). Since BFR resistance exercise (BFRRE) is performed with low loads, usually <50% of 1RM, it is thought to result in less mechanical stress, and thus also less damage to muscular structures, than heavy load strength training. However, BFRRE induces high levels of metabolic stress (5), mainly because of the reduced blood flow to the exercising muscle. Heat shock proteins (HSPs) are a group of proteins with cytoprotective properties with the ability to bind and stabilise damaged proteins, and protect against future insults. In an unstressed state, HSPs are primarily found in the cytosol. However, upon stress they translocate and accumulate to stressed and damaged structures (2; 3). HSP27 and αB-Crystallin (αBc), are two HSPs that primarily bind to damaged (or stressed) cytoskeletal (myofibrillar) structures (3). They are therefore considered important for repair and protection against exercise induced cytoskeletal damage, as often seen after heavy load strength training. HSP27 and αBc have been reported to translocate rapidly (≤ 30 min) to the cytoskeleton in rat muscles exposed to ischemic conditions (1). However, little is currently known about the HSP27 and αBc response after a bout of BFRRE in humans.
The aim of this study was to investigate the acute HSP27 and αBc response in muscles subjected to low load BFRRE.

METHODS

Seven males and two females (26±3 years, 177±7 cm, 79±11 kg), with no experience with BFR, performed five sets of unilateral knee extensions to failure at 30% of 1RM with partial blood flow restriction induced by a 10 cm wide pressure cuff inflated to 90 – 100 mm Hg. With the same load, equal numbers of repetitions was performed with the contralateral free flow control-leg. Subjects were given 45 seconds of rest between sets. Biopsies of *m. vastus lateralis* was sampled before, 1h, 24h and 48h post-exercise using a modified Bergström-technique. Muscle samples (~50 mg) were homogenised in a buffer containing a cocktail of protease inhibitors, and fractionated into a cytosolic- and a cytoskeletal fraction using a commercial fractionation kit. HSP27 was analysed using ELISA and a monoclonal antibody against HSP27 (SPA-800, Enzo Life Sciences) and αBc was analysed using a dry western blot technique, and a monoclonal antibody against αBc (SPA-222, Enzo Life Sciences).

RESULTS

Cytosolic HSP27 levels were reduced in the BFRRE leg 1 hour after the exercise bout compared to pre values and was lower than in the free-flow leg ($P < 0.05$). At 24 hours the levels of cytosolic HSP27 were similar to baseline levels in both legs. One hour after exercise, the HSP27 levels in the cytoskeletal fraction were significantly elevated in both legs ($P < 0.05$), but higher in the BFRRE leg compared to the free-flow leg ($P < 0.05$). The cytoskeletal HSP27 were back to baseline 24 hours after exercise in both legs.
Cytosolic αBc levels were reduced in both legs 1 hour after exercise ($P < 0.05$), and a larger reduction was seen in the BFRRE leg than in the free-flow leg ($P < 0.05$, figure 1 left panel). Twenty-four hours post-exercise, the levels of cytosolic αBc were back to baseline, with no differences between legs.

The cytoskeletal levels of αBc were elevated in both legs 1 hour after exercise, with a larger increase in the BFRRE leg than in the free-flow at both 1 and 24 hours ($P < 0.05$, figure 1 right panel). At 48 hours, the levels were back to baseline levels in both legs.

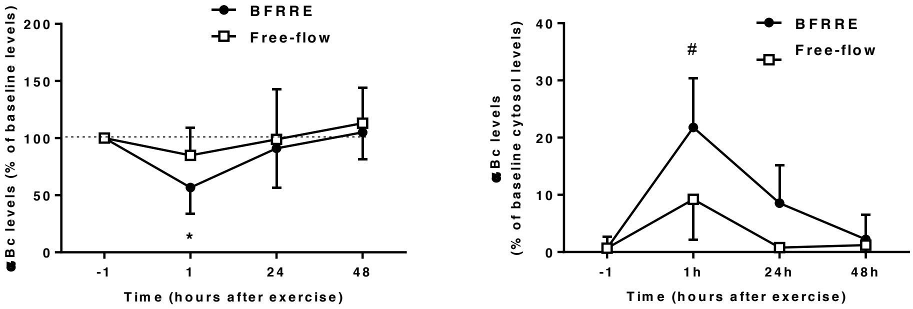

Figure 1, αBc-levels in cytosol (left) and cytoskeleton (right) for BFRRE (black) and free-flow leg (white)

DISCUSSION

Even though exercising with low loads, a HSP response was observed in both legs after exercise. However, exercising with BFR induced a more potent HSP response compared to the free-flow leg when the exercise load and volume are matched. This response was mainly seen 1h after exercise. The increased levels of HSP27 and αBc in the cytoskeletal fraction indicate an accumulation of these HSPs around the myofibrillar structures in the muscle cell, caused by a translocation from the cytosolic compartment to the myofibrillar structures. Thus, the myofibrillar structures seem to be stressed even during exercise with low loads. An interesting finding was that BFRRE induced a larger accumulation of small HSPs in the cytoskeletal fraction compared to the free-flow leg. It has earlier been shown that HSPs translocate to myofibrillar structures during maximal eccentric exercise (3), and the translocation seems related to the degree of damage (4). However, since both legs exercised with the same load, we believe that the increased HSP accumulation in the cytoskeletal fraction in this study is mainly related to the ischemic condition caused by BFR, as seen in rat models (1).

CONCLUSIONS

Low load BFRRE induced a distinct HSP-response in muscles not familiarised to this type of training. The mechanisms behind this was not studied, but is probably linked to the ischemic conditions, and therefore the high metabolic stress induced by BFRRE. However, the HSP response in muscles familiarised to BFRRE training might differ because of specific training adaptations.

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1RM PREDICTION AND LOAD-VELOCITY RELATIONSHIP

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INTRODUCTION

Maximal strength is often estimated using the force-endurance relationship, where tables or formula are used to predict one repetition maximum (1RM) or other loads (e.g. 3RM loads). For some populations (for example the frail or very young) such a procedure may not be appropriate and the accuracy of these methods depends on several parameters such as the number of repetitions, type of exercise, training background and the population used (1). Very recently, 1RM estimation from a load-velocity profiling protocol has been presented (2, 3). The aim of the present study was to investigate the ability of the load-velocity relationship to predict 1RM in different strength exercises and with different assessment devices.

METHODS

Data from four studies including in their protocol 1RM determination and load-velocity relationship profiling were gathered for the present analysis. Five common strength exercises were investigated: bench press, half-squat, horizontal press, leg curl and lat pulldown. Each study included two sessions. During the first "familiarization session" standardized positions were established for each exercise and the actual 1RM was determined. In the second "testing session", velocity was measured at three or four increasing loads ranging from 30 to 95% of the 1RM. A laboratory based inertial dynamometer, combining a linear position transducer and an accelerometer (LPT+acc) (4) was used for the half-squat and bench press exercises to determine average velocity (AvV) and peak velocity (PkV). The Myotest (Myotest, Switzerland) accelerometer was used for the bench press, leg curl, horizontal press and lat pulldown exercises to measure PkV.

The procedure to determine the "predicted 1RM" (P1RM) was as follows (Fig. 1):

1. For each subject and each exercise, the best fit load-velocity (AvV and/or PkV according to the device and exercise) relationship and linear equation was determined.
2. Associated parameters such as slope, intercept point on the Y axis (V0: maximal velocity at load=0kg) and intercept point on the X axis (Ld0: maximal load at velocity=0m.s^{-1}) were calculated for each population and then for each subject.
3. Two different methods were used to determine the 1RM. The first method (M1) consisted of determining the "1RM-Ld0 relationship" of the population and then using the linear regression to calculate individual P1RM from individual Ld0. The second method (M2) consisted of determining for the whole population the velocity corresponding to the 1RM (V1RM) and then calculating the P1RM from individual linear equation and V1RM (Fig. 1).

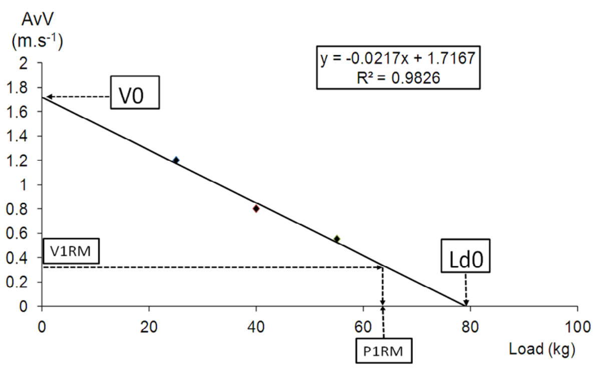

Figure 1 – Linear equation, V0 and Ld0, V1RM and P1RM determined from individual AvV-load relationship.

RESULTS

We found contrasting results for 1RM prediction (Tab. 1). Average velocity appears to be a little more relevant than peak velocity to estimate 1RM. The M2 approach was most highly correlated to actual 1RM and had lower SEE in comparison to M1. Device and parameter seemed to influence the 1RM prediction. The Myotest, that only allows peak velocity measurement, presented a lower correlation and a superior SEE for bench press exercise in comparison with LPT+acc device. Prediction ability was greater for the bench press in comparison to the half squat exercise. Correlations between the 1RM and P1RM were lower but remained acceptable in the half-squat (r=0.75, SEE=10.4%), horizontal press (r=0.71, SEE=12.4%) and lat pulldown (r=0.62, SEE=9.5%) exercises. For the leg curl exercise, the 1RM prediction was very unreliable with r≤0.22 and SEE≥42%.

Exercise	N	Device	F-V Profile	1RM	Parameter	Method	P1RM±SD	r	SEE
Half Squat	34	LPT+acc	45-60-75-90% 1RM	128(20)	AvV	M1	128±13	063	121%
						M2	129± 17	0.75	10.4%
					PeakV	M1	128± 10	0.60	13.4%
						M2	130± 23	0.51	15.2%
Bench Press	112	LPT+acc	35-50-70-95% 1RM	60 (19)	AvV	M1	60±20	0.98	6.6%
						M2	60±19	0.98	6.3%
					PeakV	M1	60±20	0.98	7.2%
						M2	60±19	0.98	6.9%
Bench Press	15	Myotest	30-60-90% 1RM	62 (12)	PeakV	M1	62±10	0.79	11.7%
						M2	62±10	0.82	11.1%
Horizontal Press	15	Myotest	30-60-90% 1RM	108 (12)	PeakV	M1	108±12	0.67	12.6%
						M2	109±18	0.71	12.4%
Lat Pulldown	15	Myotest	30-60-90% 1RM	87 (10)	PeakV	M1	87±6	0.57	10.5%
						M2	88±11	0.62	9.5%
Leg Curl	15	Myotest	30-60-90% 1RM	60 (14)	PeakV	M1	106±38	0.07	95%
						M2	66±26	0.22	42%

Table 1 *- Descriptive data and prediction characteristics (correlation "r" and standard error of estimation "SEE") for each exercise.*

DISCUSSION

Prediction of 1RM appears to be dependent on mathematical method, selected parameter (peak velocity versus average velocity), device, exercise and equipment. It is more accurate to predict the 1RM from the V1RM (M2) than from the 1RM-Ld0 relationship (M1). V1RM value has been established for each exercise and for each parameter inside our groups but need to be confirmed in a larger population. In most exercises, except for bench press, the load-AvV relationship revealed a better prediction ability than the load-PeakV relationship. AvV is more sensitive to the dynamics associated with lifting heavier loads. The load-PeakV and load-AvV relationships are not necessarily well-fitting with the same kind of equation. The method used in the present study favours the Load-AvV relationship that corresponds in most cases with a linear regression. That the Myotest device measures only PeakV could partly explain its lower prediction ability. Our results also suggest that predicting the 1RM depends on the exercise. It depends on the complexity of the movement (bench press versus squat) and on the characterisics of the machine. Most commercialised machines are not suited to dynamic inertial assessment. Leg curl for example: at the lowest load a couple of subjects would not take the risk of lifting as fast as possible as they thought they might damage the machine. For traditional exercises like bench press and squat used with free weights or guided barbell the use of load-velocity relationshp to predict the 1RM appears as accurate as traditional repetition-to-failure method and present the advantage of assessing at the same time the muscular velocity that is a very important component in many sports

CONCLUSION

Using the load-velocity relationsghip for 1RM prediction is a relevant method when the exercise allows and accurate measurement of the velocity.

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DIFFERENCES IN MECHANICAL AND MATERIAL PROPERTIES OF THE PATELLAR TENDON IN HEALTHY ATHLETES VS. ATHLETES WITH PATELLAR TENDINOPATHY

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INTRODUCTION

Volleyball is a team sport with high demands for explosive strength in the leg extensor apparatus. Unfortunately, overuse injury such as patellar tendinopathy (PT) is common, with an estimated prevalence of 40-50% among elite male players (1). The impact of tendinopathy on tendon material and mechanical properties is not well known, although one study has shown that material and mechanical properties are affected in the injured Achilles tendon (2). The aims of this project were to compare tendon mechanical properties, material properties and jump performance between athletes with PT and healthy athletes.

METHODS

20 active male volleyball players with PT and 20 healthy controls were identified from a 4-year prospective cohort study on junior elite volleyball players (2). Subjects were evaluated with respect to maximal vertical jump performance and patellar tendon mechanical and material properties. Tendon properties were examined by use of ultrasonography to assess tendon elongation, synchronized with patellar tendon force measured in an isometric knee extension chair. Also, tendon cross sectional area (CSA) and tendon length was determined with ultrasonography. Jump performance was measured on a force plate and with a volleyball specific jump and reach test (spike jump; SPJ). An unpaired t-test was applied to evaluate group differences with an alpha level of 0.05.

RESULTS

Stiffness and Young's modulus of the patellar tendon were significantly lower in the PT group compared to the control group, PT: 2259 ± 268 $N\cdot mm^{-1}$ and 0.94 ± 0.15 GPa vs. control: 2826 ± 603 $N\cdot mm^{-1}$ and 1.17 ± 0.24 GPa, respectively ($p<0.004$, n=28). Mean CSA of the patellar tendon was significantly greater in the PT group compared to the controls, 129±8 mm^2 and 122 ± 9 mm^2, respectively ($p<0.04$, n=28). (Table 1). The PT group jumped significantly higher than controls in spike jump (SPJ), 80 ± 7 cm vs. 74 ± 7 cm, respectively ($p=0.03$, n = 31). The counter movement jump - squat jump difference (CMJ-SJ) was greater in the PT group compared to that of the control group; 3.5 ± 2.3 vs. 1.2 ± 1.5 cm ($p=0.003$). (Fig. 1).

Table 1 Tendon properties for the tendinopathy group (PT) and the controls (CG). Stiffness-a and Young's Modulus-a is values calculated from the absolute force for each subject, while stiffness-r and Young's Modulus-r is calculated with greatest common force level between individuals (4000 N). Cross sectional area (CSA), Victorian Institute of Sport Assessment questionnaire for patellar tendinopathy(3) (VISAp). Values are presented as mean ± SD.

	PT (n=13)			CG (n=15)			P Value
Peak force (N)	5415	±	1186	5809	±	1213	0.394
Stiffness-a ($N*mm^{-2}$)	2569	±	490*	3684	±	1190	0.004
Stiffness-r ($N*mm^{-2}$)	2259	±	268*	2826	±	603	0.004
CSA mean (mm^2)	129	±	8*	122	±	9	0.038
Stress (MPa)	42	±	10	48	±	9	0.154
Strain (%)	6.9	±	1.0	7.1	±	1.3	0.660
Tendon Length (cm)	5.4	±	0.5	5.2	±	0.5	0.254
Elongation (mm)	3.7	±	0.6	3.6	±	0.7	0.835
Young's modulus-a (GPa)	1.07	±	0.25*	1.51	±	0.48	0.008
Young's modulus-r (GPa)	0.94	±	0.15*	1.17	±	0.24	0.008
VISAp	78.5	±	20.9	96.5	±	5.0	0.003

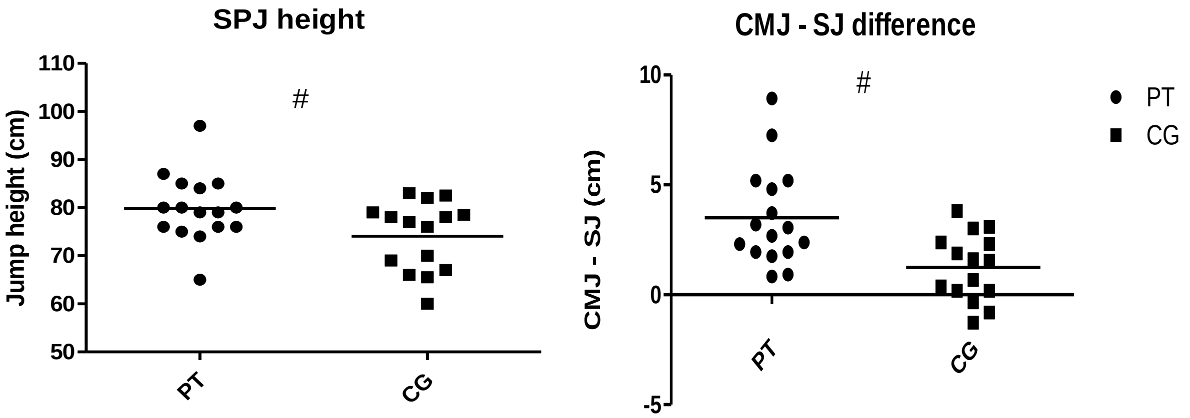

Figure 1 Jump height for SPJ (left panel) and the difference in jump height between CMJ and SJ (right panel), for PT group (round points) and CG (squared points). Horizontal line representing mean and # = significant difference p<0.05.

DISCUSSION

Stiffness and Young's modulus were lower in the PT group compared to that of the controls. The mean CSA was larger in injured tendons, which corresponds to previous clinical observations on tendons with tendinopathy (4, 5). Players with jumper's knee have been reported to suffer from this injury over a relatively long time period (1, 6). The alterations in tendon properties presented here may be one of the actual reasons for this long lasting injury. The results presented for mechanical and material properties seem to correspond with previous findings for the Achilles tendon (5). The greater jumping ability in the group with tendinopathy seems to be in line with recent studies that link augmented jump performance and greater magnitudes of jump specific training to prevalence of patellar tendinopathy (2, 7), likely due to greater loading of the patellar tendon over time.

CONCLUSIONS

The results of the present study shows differences in tendon properties in the patellar tendon of athletes with PT compared to a matched control group. Interestingly, jump performance seems not to be impaired with this condition. With these results in mind more customized training programs may be developed for athletes with patellar tendinopathy.

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EIGHT WEEKS OF STRENGTH TRAINING ENHANCES THE NUMBER OF MYONUCLEI IN TYPE II FIBERS, BUT THIS IS BLOCKED WITH SUPPRESSED TESTOSTERONE LEVELS

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INTRODUCTION

Strength training induced muscle hypertrophy is initiated by a number of complex molecular events. We know that activation of satellite cells and increases in myonuclei are two important mechanisms in muscle growth, where the myonuclei number is increased to satisfy the demand of increased protein synthesis (Kadi 2000, Kadi et al. 2004).

During a strength training session, plasma testosterone increases and remains elevated following the training session (Kraemer et al. 1990, Kvorning et al. 2007). Satellite cells and myonuclei are targets of testosterone action through androgen receptors (Doumit et al. 1996, Sinha-Hikim et al. 2004, Kadi 2008). There seems to be a relation between androgen steroid (i.e. testosterone) use and increased content of myonuclei in muscle compared to non-steroid using matched subjects (Kadi 2008), but it still remains to be clarified whether satellite cells and myonuclei addition, in relation to strength training induced muscle hypertrophy, is influenced by endogenous testosterone.

Previously published results from this study showed that suppression of testosterone production (by GnRH-analogue treatment) in parallel with strength training attenuates the response to training stimulus. This included a reduced increase in muscle mass and no gain in muscle strength after 8 weeks of strength training (Kvorning et al. 2006). In spite of both blocked acute responses and very low resting levels of endogenous testosterone in the GnRH-analogue treated group, strength training resulted in a similar mRNA expression of myoD, myogenin, IGF-IEa, IGF-IEb, IGF-IEc, myostatin, and androgen receptor as observed in a placebo group showing significant acute responses of testosterone to strength training and 10 - 20 times' higher resting levels of testosterone (Kvorning et al. 2007). In addition, the same two groups of subjects increased the number of satellite cells to a similar extent in type II fibers whereas no significant changes were observed in type I fibers (Kvorning et al. 2008).

Further analysis were performed on the same group of subjects, with the aim to investigate how suppression of endogenous testosterone influences the extent of myonuclei accretion during the time course of an 8 week strength training period. We hypothesize that suppression of endogenous testosterone will lead to a less pronounced accretion of myonuclei compared to a placebo group. In addition, a micro array analysis was performed to test for other potential satellite cell regulating mechanisms and if other relevant genes are affected by major alterations in testosterone levels.

METHODS

Twenty-two moderately trained young men participated in this randomized, placebo-controlled, and double-blinded intervention study. The participants were randomized for treatment with a GnRH-analogue (Goserelin, n=12) or placebo (Placebo, n=10) for a period of 12 weeks. The treatment with a GnRH-analogue (goserelin, 3.6 mg every 4 weeks) resulted in a testosterone level that was 10-20 times lower compared with Placebo. The strength training period of 8 weeks started after 4 weeks of treatment and included exercises for all major muscles (3 - 4 sets per exercise x 6 - 10 repetitions with corresponding 6 - 10 repetition maximum (RM) loads, 3/week). Biopsies were obtained from the mid-portion of the vastus lateralis muscle. The first biopsy was taken in the right leg and served as a before-training period biopsy. In connection to the second last strength training session, one biopsy was taken in the right leg before start of the training session and served both as an after-training period biopsy and a before-training session biopsy. This biopsy was taken 48 hours after the previous strength training session. The subjects then completed the exercises and another biopsy was taken in the left leg 4 hours after completion of the strength training session (Post4h). Myonuclei were analyzed in accordance with the methods described by Kadi et al. 2004. Microarray: 9 samples (5 Placebo, 4 Goserelin) from the Post4h were analyzed on Affymetrix HG-U133 Plus 2.0 microarrays (RMA normalized). Comparison with FDR < 0.05 resulted in a single probe set, whereas raw-p <0.05 and fold-change above 1.5 gave 36 probe sets significantly different between Placebo and Goserelin. A two-way repeated measure ANOVA was used to test for statistical significance at the level of $p<0.05$. All data are presented as means ± SE.

RESULTS

The number of myonuclear counting per fiber are shown in Table 1. The Goserelin showed no changes in myonuclear number in either fiber types. No changes were seen in type I in either group whereas strength training increased myonuclear number significantly in type II in Placebo, compared to Goserelin ($p<0.05$). There were no correlation between myonuclei per fiber and fiber size, neither for type I and II fibers. Micro array analysis revealed few changes in mRNA with no clear relation to normal vs. low testosterone levels.

Table 1. Myonuclear number per fiber type I and type II, before and after 8 weeks of strength training.

	Type I		Type II	
	Before	After	Before	After
Goserelin (n=6)	2.04 ± 0.09	2.01 ± 0.15	2.01 ± 0.15	2.10 ± 0.13
Placebo (n=8)	1.83 ± 0.15	2.07 ± 0.15	2.07 ± 0.15	2.35 ± 0.13*#

*Significantly different from before training ($p<0.05$). #Significant treatment effect ($p<0.05$).

DISCUSSION

In our previous findings, the training induced increase in satellite cells were unaffected by suppressed endogenous testosterone (Kvorning et al. 2008). The present results show that the significant larger muscle hypertrophy seen in Placebo was accompanied by a significant addition of myonuclei in type II fibers. This finding supports the demand of myonuclear addition in hypertrofying muscles (Allen et al. 1995, Kadi & Thornell 2000, Kadi et al. 2004). Furthermore, testosterone induced muscle hypertrophy has been shown to be associated with a dose-dependent increase in myonuclear number (Sinha-Hikim et al. 2002). Moreover, Petrella and co-workers reported myonuclear accretion as a result of strength training and gain in muscle mass and interestingly, the rate of myonuclear accretion lagged behind the rate of muscle hypertrophy (Petrella et al. 2008). If we relate this to the present study, this could suggest that satellite cells are activated similar in both groups independently of the level of testosterone, due to a similar mRNA expression of myoD, myogenin, IGF-IEa, IGF-IEb, IGF-IEc and myostatin and for the reason of a significant increase in muscle mass in Placebo and Goserelin although significantly larger in Placebo (Kvorning et al. 2006, 2007). In a way, satellite cells is activated "for safety reasons" and thus overshooting the needs whereas myonuclear accretion is regulated by the need (i.e. muscle mass driven). Similar satellite cell activation, but decreased number of myounuclei with suppressed testosterone point towards a role of testosterone in the process forming myonuclei.

CONCLUSION

In conclusion, eight weeks of strength training enhances the number of myonuclei in type II fibers, but this is largely blocked with suppressed testosterone levels.

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DORSIFLEXOR STRENGHT CURVES OF YOUNG AND OLDER ADULTS

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INTRODUCTION

Dorsiflexor strength training is recommended for active ankle joint control and as a potential preventive strategy against overpronation syndromes in runners (Hagen et al., 2006) and for enhancing lateral ankle stability (Hagen et al., 2012). To improve or maintain musculoskeletal health, variable-cam resistance training machines are considered adventageous because the angle-torque relationship of the target muscles (strength curves) is taken into account. The isometric strength curve of a functional muscle group depends on the biomechanical working conditions of the target muscles and the joint geometry (Kulig et al., 1984). Tsunoda et al. (1993) assume that differences in peak force of the elbow flexor strength curves between untrained men, woman and male bodybuilders are due to differences in the pennation angle of the muscle fibres which influences the physiological cross sectional area (PCSA). The purpose of our study was to investigate how the strength curves of the dorsiflexors vary between men and women and change with increasing age. On the basis of these results the shape a variable cam might be reconsidered to fulfil the demands of optimized resistance training machine for older people.

METHODS

11 male and 14 female physically healthy sport students as well as 15 male and 12 female physical healthy seniors took part in the study. After familiarization with the setup, maximum voluntary isometric dorsiflexor strength measurements of the foot were performed in two separate test sessions. The choice of the right or left foot was randomized. In a randomized order 10 different joint angle positions across the possible active range of motion were measured in a dorsiflexor training machine (B8, Kieser Training, Switzerland). In a seated position wearing commercial running shoe the subjects were instructed to perform maximum voluntary contractions with their dorsiflexors without moving their knee and hip joint. The foot was placed in the apparatus so that the ankle axis corresponded to the machine axis. An electrogoniometer (Megatron MP 10) was attached to the machine axis for quantifying joint angle. A force transducer (Kistler 9321B) measured the exerted force between the apparatus and the weight block. For data analysis repeated-measures ANOVAs ($p<0.05$) were applied to analyze mean values. For statistical comparison the angle-force relationship was normalized for each subject to a percentage of the peak force that they achieved across the 10 joint angles.

RESULTS

The shape of the strength curves of all subjects shows an ascending-descending characteristic. In the strength curves normalized to a percentage of peak force relationship differences were found in joint ankle ($p<0.01$), between young men (JM) and young women (JF) ($p<0.05$) (Fig. 1) and between JM and the male senior subjects (SM) ($p<0.05$) (Fig.2.). Significant differences between these groups were especially found in the most dorsi flexed and plantar flexed joint angles.

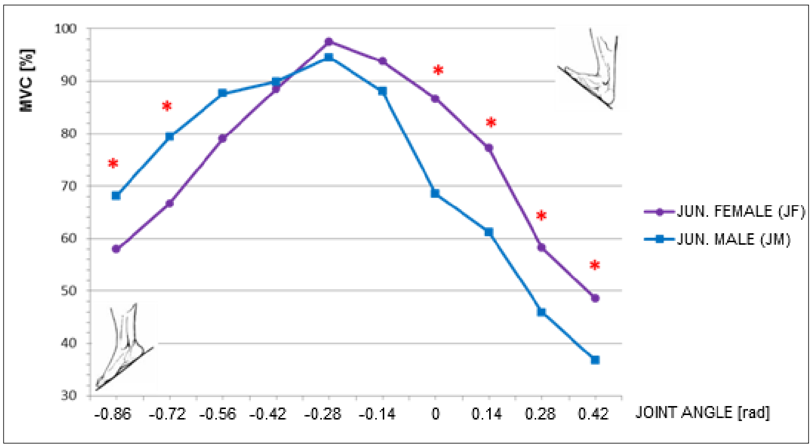

Fig. 1 Differences of the dorsiflexor strength curves normalized to a percentage of peak force relationship of younger male and female subjects

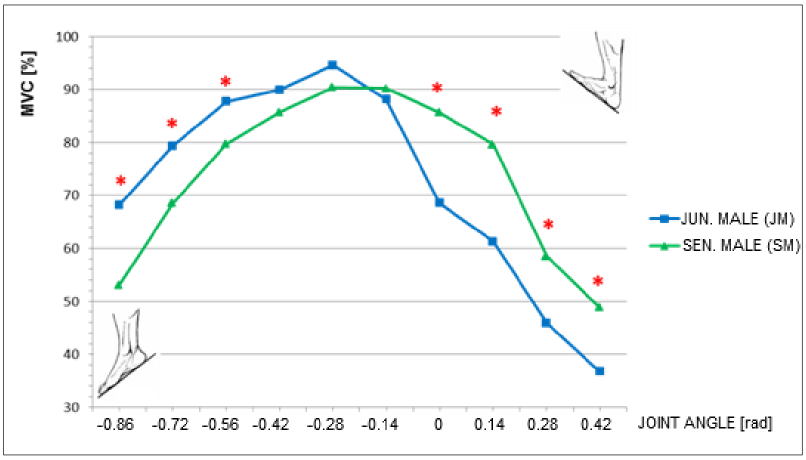

Fig. 2 Dorsiflexor strength curves normalized to a percentage of peak force relationship of younger male and senior male subjects

DISCUSSION

Despite statistically significant differences in maximum voluntary strength of the dorsiflexor muscles the shape of the strength curves is unchanged with increasing age. Differences in the most plantar flexed and dorsi flexed joint angles maybe due to age-related changes in joint flexibility and should be considered in training with older people.

CONCLUSION

For the strength training practice the results of this study mean that the dorsiflexors of younger and older can be trained with the same variable cam.

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ACUTE METABOLIC AND MECHANICAL RESPONSE TO RESISTANCE TRAINING PERFORMED AT MAXIMAL INTENDED VS. HALF-MAXIMAL LIFTING VELOCITY IN THE BENCH PRESS EXERCISE

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INTRODUCTION

One variable whose role has not been sufficiently investigated when designing resistance training (RT) programs is movement velocity [1]. We have recently shown that mean velocity can be used to adequately estimate loading intensity (%1RM) in the bench press [2] and that velocity loss allows to objectively quantify neuromuscular fatigue during RT [3]. This study aimed to compare the acute metabolic and mechanical response of bench press (BP) exercise protocols that only differed in the actual lifting velocity of every repetition performed: maximal intended velocity (MaxV) versus haf-maximal velocity (HalfV).

METHODS

Ten moderately strength-trained adult males (age 29.3 ± 5.1 yr, height 178.7 ± 9.0 cm, body mass 78.5 ± 9.1 kg, body fat 12.0 ± 3.1 %, 1RM concentric BP 77.5 ± 12.7 kg), undertook a total of six RT sessions in the BP exercise (two per week) during a 3-wk period in the following order: 3 x 8 rep with 60% 1RM at MaxV (~0.79 m/s), 3 x 8 rep with 60% 1RM at HalfV (~0.40 m/s), 3 x 6 rep with 70% 1RM at MaxV (~0.62 m/s), 3 x 6 rep with 70% 1RM at HalfV (~0.31 m/s), 3 x 3 rep with 80% 1RM at MaxV (~0.47 m/s), 3 x 3 rep with 80% 1RM at HalfV (~0.24 m/s); always with 3-min inter-set rests. The number of repetitions performed in each set was approximately half the maximum possible number that could be completed with each selected load. This was a necessary requisite so that the subjects could be able to complete all repetitions at the desired velocity in the HalfV condition. Sessions were performed at the same time of day (± 1 h) for each subject under the same environmental conditions (20ºC and 60% humidity) and separated by 48-72 h. Subjects were not allowed to take part in any other strenuous physical activity during the study. A standardized warm-up protocol consisting of 4 sets of 6, 6, 4 and 2 repetitions of increasing loads was strictly followed, always using the same absolute loads for each subject. Whole capillary blood samples were collected at rest as well as 1-min post-exercise for the assessment of lactate and ammonia. Velocity loss with the ~1 m/s (V1) load pre-post exercise was examined as a measure of neuromuscular fatigue. Three repetitions against the V1 load were performed before (at the end of the warm-up) and ~75 s following each exercise protocol (after blood sampling). The percent change in MPV pre–post exercise attained against the V1 load (mean of 3 reps) was computed [3]. The outcome variable used for all velocity measurements was mean propulsive velocity (MPV) [4]. The exact protocol of the BP exercise has been described elsewhere [4]. MPV was monitored in each session and auditory feedback provided in real time for every repetition by means of a linear velocity transducer sampling at 1,000 Hz (T-Force System, Ergotech, Spain). Subjects received verbal cues to perform each repetition either at MaxV or at HalfV according to the corresponding session. The Lactate Pro LT-1710 (Arkray, Kyoto, Japan) portable analyzer was used for lactate measurements. Ammonia was measured using PocketChem BA PA-4130 (Menarini Diagnostics, Italy). A t-test for paired samples was used to compare mean differences between the two conditions (MaxV vs. HalfV). Values are reported as mean ± SD. Effect sizes were calculated using *Hedge*'s g as follows: g = (mean MaxV – mean HalfV)/combined SD. Statistical significance was accepted at $P < 0.05$.

RESULTS

Blood lactate was higher when repetitions were performed at maximal intended velocity (MaxV) compared to when they were performed intentionally slower at half-velocity (HalfV). Lactate was significantly higher for the MaxV condition in the 3x8 with 60% RM and 3x6 with 70% RM exercise sessions, i.e. in those protocols where a higher number of repetitions were completed in each set, whereas no significant differences were found in the 3x3 with 80% RM session (Fig. 1). No significant differences were observed between the two exercise conditions for blood ammonia, although higher ammonia levels were found for the MaxV condition in the 3x8 with 60% RM session (Fig. 2).

Figure 1

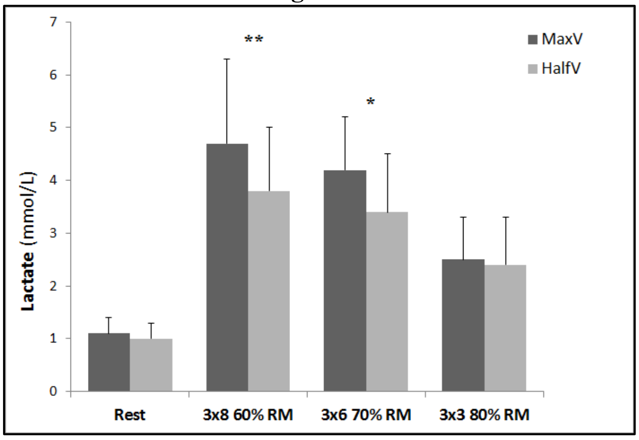
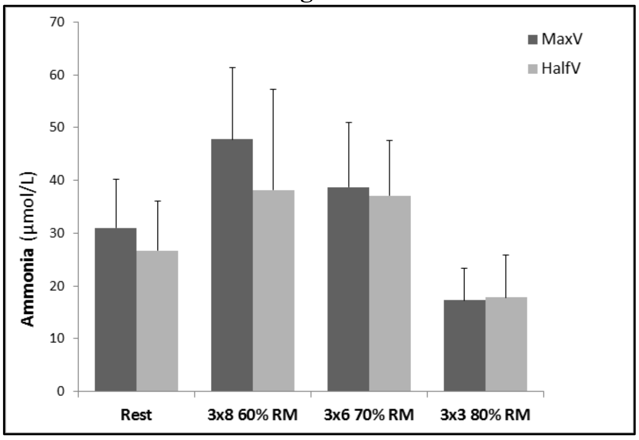


Figure 2



Significant differences: * $P < 0.05$, ** $P < 0.01$

Losses of MPV pre-post exercise against the V1 load were significant in the 3x8 with 60% RM session, with greater losses observed for the MaxV condition (Table 1). Although not statistically significant, there was a tendency for greater velocity losses in the 3x6 with 70% RM session for the MaxV condition.

Table 1. Percent change in MPV pre–post exercise against the 1 m/s load following each RT protocol.

	MaxV	HalfV	P	Effect Size
3x8 with 60% RM	7.6 ± 6.7 %	1.4 ± 7.5 %	< 0.01	0.88
3x6 with 70% RM	7.1 ± 5.5 %	3.9 ± 5.1 %	NS	0.61
3x3 with 80% RM	0.5 ± 6.5 %	1.2 ± 3.5 %	NS	0.13

DISCUSSION

Metabolic stress and neuromuscular fatigue tend to be higher when each repetition of a training set is performed at maximal intended velocity compared to half-maximal velocity. From the results of this study, it seems evident that both faster movement velocities and greater number of repetitions performed during resistance exercise cause higher lactate values, indicating that any of these factors contribute to an increased rate of glycolysis in muscle fibers. Maximal intended lifting velocities demand the recruitment of fast motor units which produce higher lactate levels. Stimulation of fast-twitch muscle fibers is important for inducing muscle hypertrophy and specific strength gains directed towards improving performance in 'explosive' sports. Following the type of RT exercise protocols described in this study (low 'level of effort'), ammonia did not rise above typical resting values (≤ 50 μmol/L), which is in accordance with recent reported results from our research group [3]. Since the present study design required us to use few repetitions per set, only low to moderate levels of blood lactate and ammonia were observed which was an expected result.

CONCLUSION

Movement velocity is a fundamental component of exercise intensity during RT. Future experimental research should further explore the effects of training with maximal vs. submaximal intended velocity on neuromuscular performance.

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THE 2.5 MINUTE REPEATED JUMP TEST: EVALUATING ANAEROBIC CAPACITY IN ALPINE SKI RACERS WITH LOADED COUNTERMOVEMENT JUMPS

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INTRODUCTION

The complexity of alpine ski racing leads to differences of opinion among sport scientists as to exactly what physiological parameters are important to racing success because the physiological demands are not easily quantified [1]. However Bosco [2] asserted that speed endurance, measured with continuous jumps is the most important physical capacity for ski racers. What can be stated with certainty is that the ability to maintain muscular power throughout a race is not only important to performance but also to the safety of the athlete. Therefore anaerobic power and capacity in alpine ski racers should be trained and tested. The purpose of this study was to compare anaerobic power and capacity before and after the offseason training period with a 2.5 minute repeated jump test (RJT).

METHODS

Nine male members of the Austrian national junior alpine ski team (18.3 ± 0.9 years) performed the 2.5 minute repeated jump test (RJT) in June and October 2009 before the start of the 2009/10 alpine ski racing season. All skiers tested were experienced with weight training, particularly in squatting and were injury free.

The RJT consisted of 60 counter movement jumps (CMJ) at a rate of one every 2.5 s with a loaded barbell equivalent to 40% bodyweight. Before the RJT, the athletes completed 1 to 2 series of squats with a weight of their choice, and then performed a few unloaded jumps. Individual CMJs with 40% bodyweight were then performed to create a reference to compare to the test CMJs. The athlete was instructed to jump as explosively and as high as possible, with 100% effort.

The vertical ground reaction forces were measured with two force platforms. The relative average power (P) of each CMJ was calculated from ground reaction forces. Each jump was numbered, and the P values for all valid jumps were recorded. Data sets were created for each athlete with missing values in the cases of invalid jumps (athlete did not jump on the plates, or counter movement depth was too shallow). A regression line was calculated for 60 jumps with missing values with Excel (Microsoft) for each athlete's test. The missing values for each athlete were then calculated with the regression equation and replaced. Each athlete then had P values for 60 CMJs. The 60 values were divided into intervals of 30 s (12 CMJ) and a mean was calculated for each interval. A mean P for the complete test was also calculated from the 60 values. The first valid CMJ of the RJT was compared to the reference CMJ (percent of reference CMJ P) as a control that the test was performed with maximal effort. The mean P for each 30 s interval was also expressed relative to the reference CMJ P. The group means for the individual P of each of the 60 jumps were used to calculate group linear regression equations for June and October.

An ANOVA with repeated measures (SPSS 18.0 for Windows) was performed for mean P of the five 30 s segments. Variables compared between June and October with Student t tests were the mean P for the entire 2.5 minute RJT, the reference CMJ P, and the percentage of the first CMJ P relative to the reference CMJ P. The y intercepts and the slopes of the P regression equations from June and October were compared using Student's t according to Zar [3]. Level of significance was set at $p < 0.05$.

RESULTS

In June the number of valid jumps was 51.3 ± 5.1 (mean ± SD) and in October 51.6 ± 4.7. Each athlete completed the test duration of 2.5 minutes and achieved at least 42 valid jumps. The ANOVA showed that the main effect of the test session (June and October) on the P of the 30 s periods was significant. The main effect of fatigue across the five 30 s intervals was also significant. There was no significant interaction between the test sessions and the five intervals, suggesting that the effect of fatigue did not change from June to October. The mean P for the 2.5 minute RJT in October (35.8 ± 3.8 $W \cdot kg^{-1}$) was significantly higher than in June (33.6 ± 3.7 $W \cdot kg^{-1}$), ($p < 0.05$). The single pre-test reference CMJ increased after the preseason conditioning significantly from 37.0 ± 3.5 to 39.0 ± 4.2 $W \cdot kg^{-1}$; a 5% improvement. The P of the first test

CMJ relative to the reference CMJ in October (96.8 ± 3.5%) was not significantly different from that in June (96.2 ± 5.2%). The 30 s mean P relative to the reference CMJ decreased with time and this decrease was similar for both test sessions (see Fig. 1). The y intercept in October (38.6 $W\cdot kg^{-1}$) was significantly higher than in June (36.7 $W\cdot kg^{-1}$) which indicates that the regression of the CMJ P was elevated but there was no significant difference between the slopes of the P regression lines for June ($y = -0.1023x + 36.7\ W\cdot kg^{-1}$) and October ($y = -0.0911x + 38.6\ W\cdot kg^{-1}$).

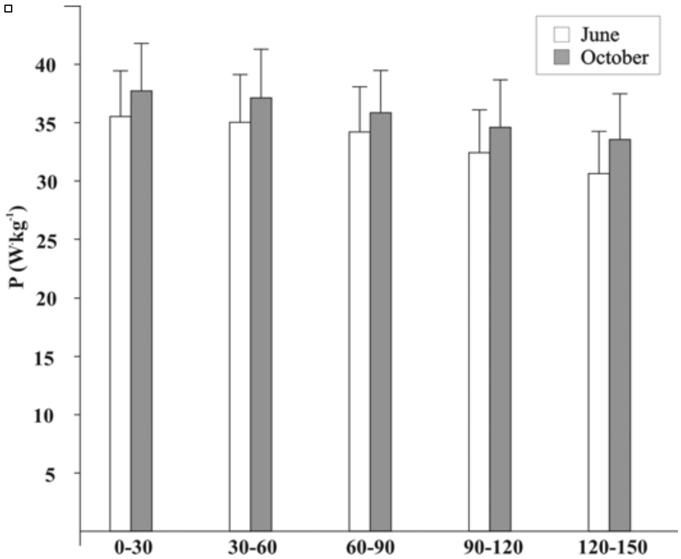

Figure 1: Mean 30 s P for five intervals (mean ± SD)

DISCUSSION

The athletes improved their ability to both produce and maintain anaerobic power from June to October. The increases in the reference CMJ P and the y intercept of the P regression are indicative of better power production. The slope of the regression did not change but the y intercept was elevated, resulting in a higher P at 2.5 minutes indicating improved power maintenance, also reflected in the higher mean P for the entire RJT.

Bosco's group worked with the Italian ski team and compared test results in 1994 with those in 1989 for 7 male athletes [2]. They found 7-8% improvements in 15 s mean jump heights for 15 s and 30 s intervals but no changes for 45 s or 60 s. In contrast, Alberto Tomba (Olympic champion, SL & GS 1988, SL 1992, world champion SL & GS 1996) improved over 25% in the first three 15 s periods and by about 13% for the last period. Tomba's superior anaerobic capacity would contribute to his success, but it is impossible to estimate the effect of this on his races.

Simulating ski racing in a lab is impossible, but tests should resemble physical demands of racing. The RJT is appropriate as an anaerobic test for all alpine ski racers because the 60 jumps simulate the approximate number of gates in slalom and giant races and the 2.5 minutes is equivalent to the duration of the longest downhill race.

CONCLUSIONS

The present investigation showed that anaerobic power and capacity improved during the offseason training period, as evidenced by results of the RJT. The reference CMJ P increased, as did the y intercept of the regression for P, indicating higher initial anaerobic power production. The relative effect of fatigue did not change, reflected by the unchanged slope of the regression, but the elevated regression and the higher mean P for 2.5 minutes demonstrate an improved anaerobic capacity.

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EFFECTS OF A SIX-MONTHS STRENGTH TRAINING COMBINED WITH REHABILITATION SPORTS FOR INTERNAL DISEASES (TERTIARY PREVENTION) ON TYPE 2 DIABETICS

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INTRODUCTION

The rapid increase of the incidence-rate of type 2 diabetes mellitus is a global problem (IDF, 2009). Lifestyle intervention with physical exercise on a regular basis plays a central therapeutic role. Following this therapeutic approach the aim of this study was to determine to which extent the findings differ if one research group is to participate in a device-supported strength endurance training combined with additional rehabilitation sport adapted for the individual indication, whereas the other group performs placebo rehabilitation exercises in addition to the device-supported strength endurance training.

METHODS

In this survey 55 patients with type 2 diabetes mellitus have been randomised in two groups. The first group (GR1) completes placebo rehabilitation exercises followed by a strength endurance training twice a week. The second group (GR2) completes a strength endurance training combined with internal rehabilitation sports twice a week. Strength endurance training was predefined with 20-25 reps and 8 exercises with using great muscle groups. The subjective sense for intensity after 4 weeks should be „middle to a little exhausting“ (Buskies, 1999). Rehabilitation sport means gymnastic with high components of endurance exercises for one hour per session to burn more calories than group 1. Placebo rehabilitation exercise means the patients absolve a warm up for 15 minutes in a group, speak with the instructor and complete the same strenght endurance training like group 2. The intension was to find out how important is the calorie consumption in the training session. The patients in both groups should think they do the same. At the beginning and directly after the end of the six-month intervention the following data have been measured for comparative purposes: HbA1c (haemoglobin), drug application, anthropometric variables, fat free mass (without bone mass) determined by means of bio impedance, resting metabolic rate determined by means of spirometrical measurement and maximum strength.

RESULTS

During the intervention period five patients quitted GR1, another five GR2. The HbA1c level dropped in GR1 from 6.87±0.78% to 6.65±0.70% (p=0.013), in GR2 from 6.81±0.55% to 6.74±0.71% (p=0.173). In GR1 the attending general practitioner reduced the dosage of the antidiabetic medication in five cases. In one case the dosage had to be increased. In GR2 the need for antidiabetic medication was reduced in one case.

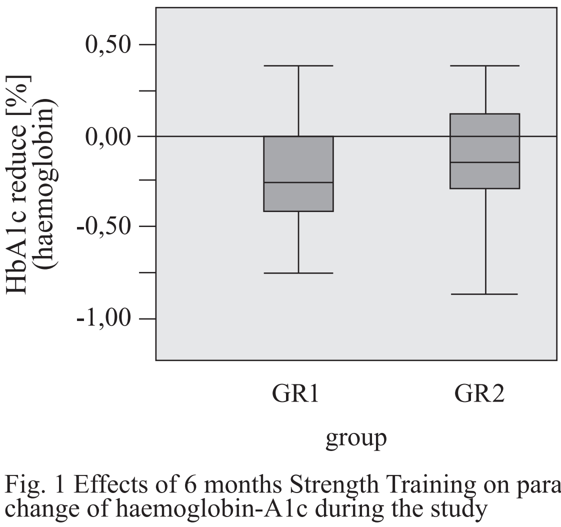

Fig. 1 Effects of 6 months Strength Training on parameter change of haemoglobin-A1c during the study

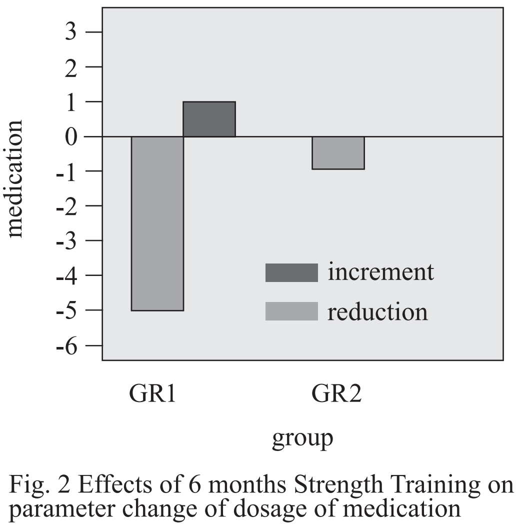

Fig. 2 Effects of 6 months Strength Training on parameter change of dosage of medication

The fat free mass ration increased in GR1 from 61.75±7.50 % to 65.66±8.68 % (p=0.000) and in GR2 from 60.50±7.71% to 63.64±8.09% (p=0.000). The resting metabolic rate (in kcal/kg/d) increased in GR1 from 23.12±5.18 to 26.70±4.93 (p=0.001), in GR2 from 23.27±5.67 to 24.61±6.26 (p=0.170).

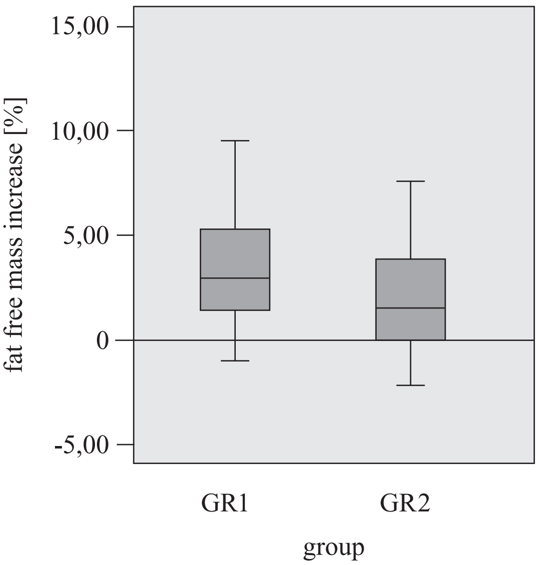

Fig. 3 Effects of 6 months Strength Training on parameter change of fat free mass (%)

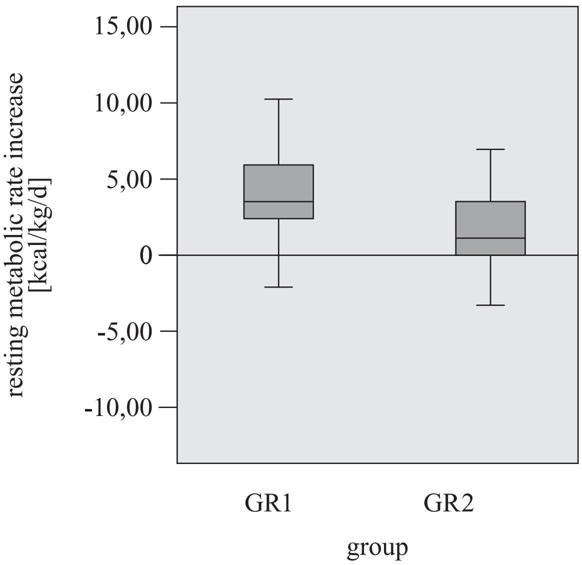

Fig. 4 Effects of 6 months Strength Training on parameter change of resting metabolic rate (kcal/kg/d)

Further highly significant changes in both groups could be established concerning strength of lumbar spine extension and strength lumbar spine flexion. In GR1 the strength of lumbar spine extension increased from 33.1±15.5kg to 59.2±19.5kg (p=0.000). The strength of lumbar spine flexion increased from 28.9±13.2kg to 45.5±16.4kg (p=0.000). Regarding GR2 a rise in strength of lumbar spine extension from 25.6±12.9kg to 46.8±17.9kg (p=0.000) could be established. The strength of lumbar spine flexion increased from 19.9±10.5kg to 36.7±15.7kg (p=0.000). Comparing the two groups no significant differences could be assessed in the change in value.

DISCUSSION

After the six-month sport intervention the group 1 completing placebo rehabilitation exercises showed a significant drop of the HbA1c level. The dosage of antidiabetic medication could mostly be reduced.
The group 2 taking part in internal rehabilitation sport showed no significant drop of the Hba1c level. The muscle mass ratio could be increased significantly in both groups, whereas only GR1 showed a significant increase of the resting metabolic rate. There was no significant difference between group 1 and 2. This distinctions intra-group with different contents of exercises is conform with the meta-analysis from Saam/Kann/Ivan (2006), even though the differences were not statistically significant. However, as building-up muscle mass and improving insulin sensitivity reflected by lower haemoglobin-A1c is a long term process, a longer intervention would be needed to achieve significant difference.

CONCLUSION

In summary, all patients benefited from the sport intervention, with regard to their medication dosage and their muscle mass ratio. However, changes in medication dosage an HbA1c level were considerably higher in GR1, the placebo rehabilitation sports group. There are research potential in long term studies.

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EFFECT OF BICARBONATE SUPPLEMENTATION ON MALE TOP-LEVEL ROWERS

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INTRODUCTION

A review over performance benefits achieved from bicarbonate loading in athletes competing with maximal intensity over 1-7 min, suggests that the best protocols for bicarbonate loading should involve a dose of 0,3 g/kg BM pure $NaHCO_3$, which should be taken 120-150 min before the start of the competition (e.g. Carr et al., 2011). However, the main challenge with different bicarbonate loading protocols has been increased gastro-intestinal (GI) stress the last hours before competition, with potential negative effects on performance. Consequently, emphasis has been put on exactly how the bicarbonate supplement should be administered in the last hours before competitions (Carr et al., 2011). Furthermore, most evidence for ergogenic effects of optimal bicarbonate loading protocols arise from studies on moderate level athletes. Therefore, the aim of this study was investigate the effect of an "optimal" bicarbonate loading protocol on GI-stress and performance in elite rowers.

METHODS

Six Norwegian male top-level rowers performed two 2000 m rowing ergometer tests separated by 5 days. The rowers were randomized to take either bicarbonate capsules (0.3g/kg body mass), or placebo capsules before the first, and the opposite before the second test. The content in each capsule was 1 g pure $NaHCO_3$ or placebo. The capsules were taken together with water in 5 doses over 60 min (1 dose every 15 min), in the period 180-120 min prior to the test. Capillary blood samples from the fingertips were taken 60, 30 and 2 minutes before, as well as 2, 30 and 60 minutes after the tests. Blood samples were analysed by ABL80 FLEX blood gas analyser (Radiometer, Copenhagen, Denmark).

RESULTS

The bicarbonate supplementation protocol successfully increased HCO_3^- blood levels (figure 1) and increased pH by 0.8±0.2 units across the experiment. The rowers performed 2.2±1.4 seconds better with bicarbonate supplementation (p=0.02, figure 2). It was a uniform effect, where six out of six rowers increased their performance.

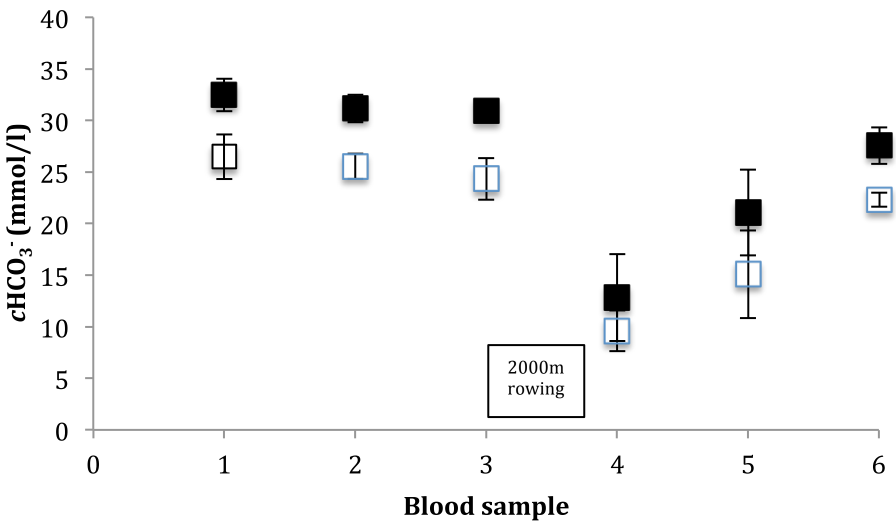

Figure 1. Concentration of bicarbonate in plasma prior to and after the test (1=-60 min, 2= -30 min, 3= -2 min, 4= +2 min, 5= +30 min and 6= +60 min), with bicarbonate supplementation (filled) and without (open).

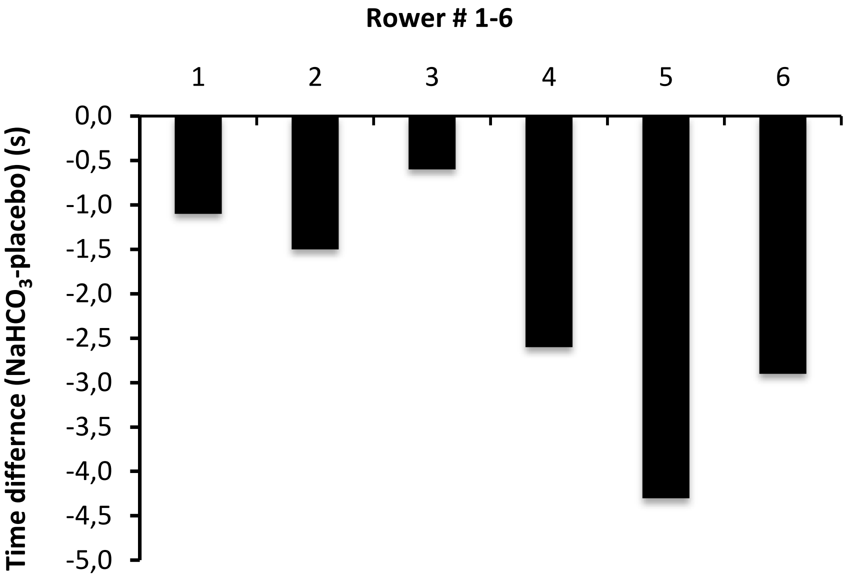

Figure 2. Time difference (s) in 2000 m rowing-ergometer performance between the bicarbonate trial and the placebo trial in each of the 6 rowers. All rowers completed the bicarbonate trial 0.5-4.5 s faster than the placebo trial.

No significant side effects (GI-stress) of the loading protocol were reported by any of the rowers; however, some rowers reported a tendency towards increased need to belch and minor stomach growling.

DISCUSSION

The loading protocol used in this study successfully increased HCO_3^- blood levels and raised blood pH levels without giving any significant detrimental side effects. More importantly, all six rowers performed better in the bicarbonate trial than in the placebo trial, indicating that the ergogenic effects of bicarbonate loading protocols observed in moderate level athletes also seems to persist in elite athletes.

CONCLUSIONS

The bicarbonate loading protocol used in this study successfully improved 2000 m rowing-ergometer performance in elite rowers without causing significant side effects.

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Poster Only

Posters will stay on poster walls during the whole conference.
(Sports Hall)

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Strength training versus concurrent training in non-linear periodization: effects on strength gain in adult women

Black, Andrew
Hormonal response to free weight and machine weight resistance exercise

Carvalho, Carlos
Power and explosive strength comparation between men volleyball national team players

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Individual step characteristics of repeated early acceleration in collegiate men soccer players

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Complaints of the locomotor system of dragon boaters compared to those of kayakers

STRENGTH TRAINING VERSUS CONCURRENT TRAINING IN NON-LINEAR PERIODIZATION: EFFECTS ON STRENGTH GAIN IN ADULT WOMEN

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INTRODUCTION

Strength training (ST) and aerobic training are often done in the same session, which we call concurrent training (CT). Such programs of physical conditioning and rehabilitation aim the development of different skills (Shaw et al., 2009). The great adherence to this type of training can be based on the reduction of available time for regular exercise. However, a question that is not well enlightened concerns strength gains in adult women depending on the type of training used, strength or concurrent, and there is little information in literature from the perspective of nonlinear periodization model used in CT (Chtara et al., 2008; Levin et al., 2009). Therefore, the purpose of this study was to analyze the influence on the maximum force of physically active women when submitted to strength training and concurrent training (strength and aerobic) in non-linear periodization.

METHODS

The study has started with 30 physically active women in the age of 35-55 years who were divided into two groups, strength training (ST, 12:58±72.55kg; 1:53m±0.05) and concurrent training (CT, 62.79±8.14kg; 1:53± 0.06m), both groups with 15 subjects. Eight women completed the study in each group due to the exclusion criteria. The study was approved by the home institution (CAE 0045.0.115.000-09). Anthropometric measurements (weight and height) were checked. Later, there were two weeks for adaptation on the exercises program. Then, 10 RM testing and retesting occurred according to Brown and Weir (2001). In an alternate design, the exercises used were leg press45 (LEG45), leg extension (LG) and leg curl (LC). The maximum load (1RM) for each subject was estimated from the equation 1RM = load lifted/[1.0278 - (0.0278 x maximum repetitions)], Heyward (1997). Strength Training (ST) and concurrent training (CT) groups were separated at random. The same tests were applied again 10 weeks later. Both ST and CT groups underwent 10 weeks of training in a frequency of two sessions a week, with at least 48 hours between sessions. The strength training in both groups was non-linear periodized in the following training sequence: session A (8-10RM and 70-85% 1RM), session B (3-6 RM and > 85% 1RM) and session C (12-15 RM and 60-70% 1RM), this order was followed until the last scheduled session. The execution order of the exercises was: leg press45 (LEG45), leg extension (LE) and leg curl (LC), and the training routine was completed with the bench press, lat pull down, biceps curl, triceps curl and abdominal crunch – although these last five exercises have not been evaluated. The CT group performed strength training similar to the ST, but it also performed a 20-minute aerobic training at the intensity corresponding to values between 11 and 15 on the scale of perceived exertion (Borg, 1998) before the strength training.
For the normality of the data in pre and post-training in both groups, the Shapiro-Wilk was applied. Since the data presented a normal distribution, a One Way ANOVA was applied to analyze the differences between the periods of the two groups; a Tukey post hoc evaluated the statistical differences between the periods. In order to determine the magnitude of the effect, the effect of size was used (Rhea, 2004). The significance level for statistical tests was 5%. SPSS 17.0 for Windows was used for all statistical procedures.

RESULTS

The maximum strength of the lower limb showed significant increase in ST and CT for the LEG45 ($p = 0.001$ and 0.001) and LE ($p = 0.002$ and 0.003), respectively, between the pre and post test, the same was not observed for LC exercise ($p = 0.446$ and 0.428). By observing the post test between the ST and CT group only LEG45 ($p=0.001$) and LE ($p=0.002$) were different, the LC did not show such behavior, $p = 0.098$. The same trend was noticed in the effect size after 20 sessions in group ST, table 1.

Table 1 –Values pre, post and effect size (ES) in leg press45 (LEG45), leg extension (LE) and leg curl (LC) in groups concurrent training (CT) and strength training (ST).

Exercise (kg)	ST				CT			
	Pre	Post	ES		Pre	Post	ES	
LEG45	131 (10.96)	172.5 *# (11.33)	3.77	Large	123.2 (14.74)	139.46* (25.55)	1.14	Moderate
LE	26.7 (3.97)	33.7 (5.17)*#	1.76	Large	23.7 (5.67)	27.07* (6.34)	0,59	Small
LC	17.5 (2.88)	20 (1.80)	0.86	Moderate	14 (3.16)	16 (2.33)	0.63	Small

*statistical difference with the pre-test, intragroup; #statistical difference between the post test, intergroups. Median values (standard deviation).

DISCUSSION

Our findings demonstrate that resistance training itself is more efficient in increasing the strength of adult women than when strength training is preceded by aerobic training. The exercises LEG45 and LE showed significant improvements in both protocols, but when comparing the post test (intergroup), the isolated strength training showed significantly greater improvements. The exercise LC showed no significant changes when comparing pre and post in intragroups and intergroups comparison after training as well. The effect size was greater in the three exercises in strength training itself in comparison to concurrent training. Same findings were gotten by Chtara et al. (2008). The authors observed that after 24 sessions of training on lower limb, maximum strength (1MR) increased significantly ($p < 0.01$) in all groups (group strength [+17.0%], group strength + aerobic [+12.2%], group aerobic + strength [+10.6%], group aerobic [+6.2%], and the control group [+5.6%]. Similar findings were also observed by Levin et al. (2009) once after 6 weeks of intervention on trained cyclers increased maximal strength in the squat 25% in the group that performed the ST, and 6.6% in CT, which demonstrates that the level of training is not interfered in the strength response. In our study, the subjects were considered only physically active, but with low level of experience in the ST. Another factor that may have influenced the results is related to the type of periodization, while the study by Levin et al. (2009) each session involved a characteristic of strength training (power, hypertrophy and maximum strength); in the Chtara et al. (2008) half of the sessions were muscle endurance and half power. The groups in these studies had low strength gain. In our study, there is a variation of intensity session A (70-85 % 1RM), B (> 85% 1RM) and C (60-70% 1RM) between the characteristics of hypertrophy and maximal strength, which may have enhanced the increasing in muscle strength, especially in group ST.

CONCLUSIONS

The ST is more efficient in gaining strength in the lower limb in adult women and this gain can be enhanced when the nonlinear periodization is used. Although there is also increasing muscle strength when the CT is applied, it happens on a lower scale.

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HORMONAL RESPONSE TO FREE WEIGHT AND MACHINE WEIGHT RESISTANCE EXERCISE

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INTRODUCTION

No study has examined the effect of exercise modality (free weight vs. machine weight) on the acute hormonal response using similar multi-joint exercises. The purpose of this investigation was to examine the effect of resistance exercise modality on acute hormonal responses by comparing the back squat and leg press exercises. These exercises consist of similar multi-joint lower-body muscle involvement and muscle actions.

METHODS

Ten resistance trained men (21-31 years, 24.7 ± 2.9 years, 179 ± 7 cm, 84.2 ± 10.5 kg) participated in the study. Sessions 1 and 2 determined the participants' 1-RM in the squat and leg press. During acute heavy resistance exercise testing visits (AHRET), sessions 3 and 4, participants completed 6 sets of 10 repetitions with an initial intensity of 80% of their 1-RM for the squat and leg press exercises (one exercise mode per visit). There was a 2 minute rest period between each set. Blood samples were collected before, immediately after, 15 and 30 minutes after exercise via intravenous catheter during the AHRET visits and were analyzed for testosterone, cortisol, and growth hormone concentrations. Blood lactate concentration, plasma volume change, heart rates and ratings of perceived exertion were also measured. Total work was calculated for external load only and for external load and the body mass used in the exercises. The 4 sessions were counterbalanced and randomized for exercise mode.

RESULTS

Testosterone for the squat (Pre: 23.9 ± 8.7 nmol•L-1; IP: 31.4 ± 10.3 nmol•L) and leg press (Pre: 22.1 ± 9.4 nmol•L-1; IP: 26.9 ± 7.8 nmol•L) increased after both exercises but significantly ($p<0.05$) more after the squat. Growth hormone increased in both the squat (Pre: 0.2 ± 0.2 μg/L; IP: 9.5 ± 7.3 μg/L) and the leg press (Pre: 0.3 ± 0.5 μg/L; IP: 2.8 ± 3.2 μg/L). The increase was significantly higher after the squat compared to the leg press. Cortisol also increased after performing the squat (Pre: 471.9 ± 167.2 nmol•L-1; IP: 603.2 ± 277.6 nmol•L) and leg press (Pre: 463.5 ± 212.4 nmol•L-1; IP: 520.3 ± 270.3 nmol•L), but there was no difference between the two modes. The total work when including body mass moved was significantly higher for the squat (60.5 ± 10.8 kj) compared to the leg press (42.9 ± 7.0 kj). Blood lactate for the squat (Pre: 1.1 ± 0.4; IP: 10.9 ± 2.3) and leg press (Pre: 1.1 ± 0.5; IP: 7.5 ± 2.6) increased after exercise, but a significantly greater increase was found for the squat.

DISCUSSION

Greater testosterone, growth hormone, and lactate responses were observed after performing the squat exercise compared to the leg press. These findings suggest that squat exercise is more effective at inducing an acute hormonal response. If the leg press exercise is used, the hormonal response may be reduced possibly leading to reduced training adaptations.

CONCLUSION

These results indicate that free weight exercises may induce greater hormonal responses to resistance exercise.

POWER AND EXPLOSIVE STRENGTH COMPARATION BETWEEN MEN VOLLEYBALL NATIONAL TEAM PLAYERS

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[2]Human Movement Laboratory; Higher Education Institute of Maia; Portugal

INTRODUCTION

Explosive concentric strength and muscle power are primary factors for successful performance in volleyball [1, 2]. In fact, high performance in volleyball requires a dynamic combination of eccentric and concentric contractions that decisively affect the specific volleyball performance.

This neuromuscular pattern is highly reproduced during the performance of vertical jumps which supports its use in the past few decades to assess the lower limbs power [3]. Vertical jump performance involving both legs is a closed chain movement with different muscle activation patterns and a knee angular velocity not limited which allows a transfer of energy between joints [4], as it happens, for instance during the stretch-shortening cycle.

Isokinetic assessment is generally performed during single joint open kinetic chain movements (e.g. knee extension) and it is limited to an angular velocity.

These characteristics make the isokinetic evaluation relatively nonspecific, mainly for sports where stretch-shortening cycles are frequently performed [5].

The training of power and explosive strength is decisive in the development of volleyball players' specific performance, which requires to the trainers technical knowledge's to assess and develop it in the pitch.

The main objective of this study was to describe and compare the power and explosive strength among three groups of men's volleyball national team with different vertical jump performances.

METHODS

The study involved 15 senior male players of the national volleyball team divided into three study groups according to a previous counter-movement jump performance: (A) group of athletes who have demonstrated best results, (B) group of athletes with an average performance and (C) a group of athletes with poor results (C). Note that all athletes performed three attempts for Squat Jumps (SJ) and Countermovement Jumps (CMJ) with the best one being selected. All jumps were performed on a force platform (AMTI model Bp-4100) at a sampling rate of 2000 Hz.

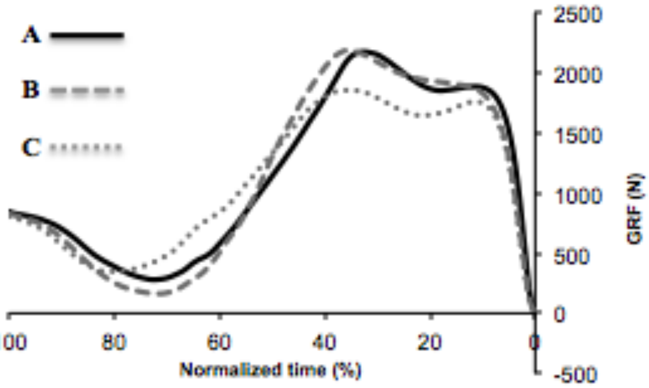
Isokinetic assessment was performed with subjects sitting with the thigh at an angle of 85^o to the trunk. During the session, the evaluation began with 5 concentric contractions at 90ºs^{-1} to the right lower limb. All tests were performed using a REV9000 (Technogym, Italy) isokinetic dynamometer.

RESULTS AND DISCUSSION

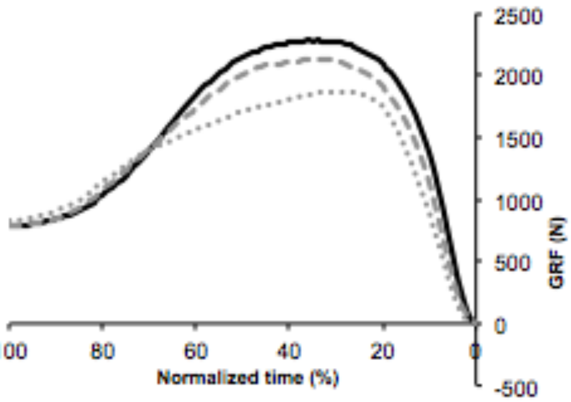
Table 1 shows that regarding to the CMJ, the group A had a greater average height performance in vertical jump comparatively to the other groups (more 8cm than group B and more 16cm than group C). In SJ test, the group A also had the highest results, 7cm and 13cm above the groups B and C respectively.

Table 1 – Results of Countermovement Jump and Squat jump tests.

	CMJ		SJ	
GROUP	**MEAN [m]**	**SD**	**MEAN [m]**	**SD**
A	0,500	± 0,012	0,405	± 0,022
B	0,425	± 0,002	0,339	± 0,029
C	0,343	± 0,030	0,277	± 0,026



a)



b)

Fig 1 - Ground Reaction Force of CMJ (a) and SJ (b) normalized by time

The Fig. 1 a) illustrates that group C does not reach at the same peak force than groups A and B. In Fig. 1 b) it is possible to see that group A developed the highest force in a shorter period of time (group A 2342N> group B 2143N> 1901N group C). This can be also confirmed in isokinetic extension strength (Fig. 2) where group A reached a higher peak torque and a faster and higher strength production.

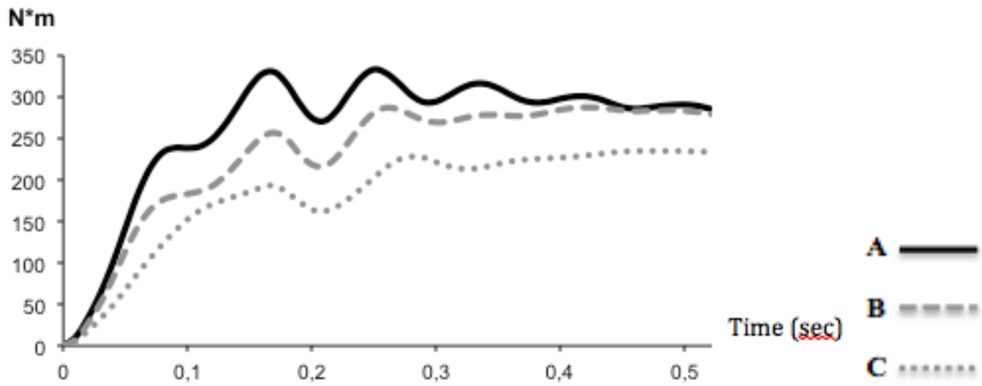


Fig 2 - Isokinetic extension concentric contractions at 90ºs^{-1}

CONCLUSIONS

This study demonstrated that the power and explosive strength are very important for volleyball players' specific performance. Additionally, it was possible to see that the best performance group (A) can generate, on average, a higher force in a shorter period of time, getting more speed and power output during counter-movement jump. Adding up, considering the fact that the group A was constituted by hitters, clearly demonstrates the importance of the lower limbs capacity to generate power in this specific playing position.

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THE INFLUENCE OF STABILIZER BELT OF LUMBAR SPINE IN STRENGTH AND POWER OF LOWER LIMB FOR A MUSCLE STRENGTHENING EXERCISE PROGRAM FOR ELDERLY ADULTS.

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INTRODUCTION

The benefits of strength training are very well described in the literature [1, 2]. They apply to different populations from frail elderly to the high performance athlete [3]. The leg extension and leg curl exercises are widely used in a training program aimed at strengthening the muscles of the lower limbs. Providing support to the lower back, the stabilizer belt of lumbar spine (SBLS) could increase efficiency and safety in the execution of these exercises. Such an effect may be of benefit not only for elite athletes, but namely in elderly subjects with relatively high (33.6%) incidence of low back pain complains. [4]. However, this tool is still rather scarcely utilized in practice during muscle strengthening programs. Objective: To assess whether the use of the SBLS affects the muscle strength and power production in during execution of seated leg extension exercise and seated leg curl exercise.

METHODS

Fifteen with coronary artery disease (CAD) male patients (age 66.5 +/- 2.5 years, weight 75.8 ± 2.5 kg, height 172.6 ± 1.7 cm), attending for at least one month a cardiac rehabilitation program were subjected to a test of maximal strength (one repetition maximum - 1RM) and power produced by lower extremity muscles while performing seated leg curl and seated leg extension. Mean power in concentric phase of exercise was measured by means of monitoring device Fitrodyne ™ The best value out of 3 maximal effort attempts performed with a rest period of 60 second was taken a criterion of the test. In the first session half of the subjects were tested with the belt, the other half another without it. In the following session after one week the groups tested were reversed. Assignment of the subject to the groups was done randomly to avoid in order of use of the belt affecting the result. Paired t-test was employed to test the statistical differences of 1RM and power in concentric phase for exercises performed with and without belt respectively.

RESULT

The 1RM of seated leg extension with belt (**1RMSLEWB)** was 83.1 ± 23.0 kg and 1RM of seated leg extension no belt (**1RMSLENB)** 91 ± 20.3 kg. The 1RM of seated leg curl with belt **(1RMSLCWB)** was 75.3 ± 18.3 kg and 1RM of seated leg curl no belt (**1RMSLCNB)** 79.6 ±17, 1 kg. In both exercises 1RM values were significantly (p 0.01) higher if exercises was performed without belt (Fig. 1). Power of seated leg extension with belt (**PSLEWB)** was 242.4 ±107.2 W and power of seated leg extension no belt (**PSLENB)** was 265.6 ±104.1 W. Power of seated leg curl with belt (**PSLCWB)** was 217.7 ± 82.5 W and power of seated leg curl no belt (**PSLCNB)** 211.5 ± 90.8. Difference in power produced in concentric phase of both exercises with and without belt were not statistically significant (Fig.2).

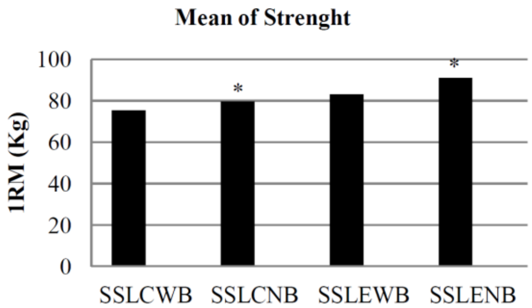

Fig. 1: 1RM in seated leg curl with belt (1RMSLCWB) and no belt (1RM SLCNB) and 1RM in seated leg extension with belt (1RMSLEWB) and no belt (1RMSLENB).

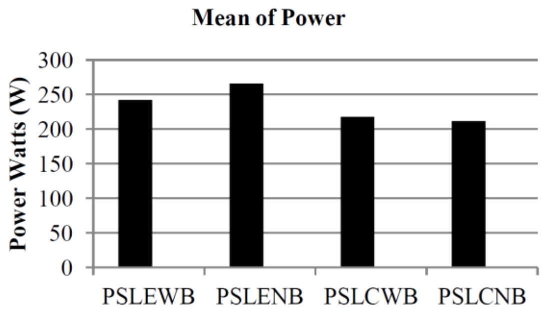

Fig. 2: Power in concentric phase of seated leg curl with belt (PSLEWB), and no belt (PSLENB) and power in concentric phase of seated leg extension with belt (PSLCWB) and no belt (PSLCNB).

DISCUSSION

Result showed a significant reduction of muscle strength expressed in 1RM for both exercises with the use of the stabilizer belt. This fact can be explained with the extension of the lumbar spine during movement without the belt, changing the point of support and increasing leverage. This demonstrates that the SBLS can better isolate the muscle groups activated and hence protect the spine by preventing the "decoupling" of the chair during movement. It can be assumed that in elderly the strength exercises of the lower limbs performed with belt can be carried out more safely.

Nevertheless, additional studies focusing on the incidence of back injury and muscle activation in the seated leg extension and leg curl exercises to enhance evidence of the efficiency of SBLS and justify its routine use.

CONCLUSION: We conclude that the SBLS reduces significantly the muscle strength in seated leg extension and seated leg curl exercise.

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BIOELECTRICAL MUSCLE ACTIVITY DURING FLAT BENCH PRESSING

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INTRODUCTION

Bench pressing is one of the most popular strength exercises, used for general conditioning by athletes of many sport disciplines. It is also part of powerlifting and a sport discipline of its own. The available data regarding bioelectrical activity of particular muscle groups during bench pressing is incomplete. The main objective of this study was to determine the input of different muscle groups during the bench press with different external loads.

METHODS

Twenty athletes with international sports level took part in this investigation. All subjects were required to have at least 5 years of weight lifting experience prior to the study.

After a general warm-up, each subject performed a specific warm-up that consisted of two sets of the bench press with 6 rep. at 60%1RM. The 1RM value was used to determine the intensities of particular bouts that were applied during the testing session. The main session included four sets of one rep. of the flat bench press with 70, 80, 90, and 100 % of 1RM.

The activity of four muscles was measured: the pectoralis major (PM) the anterior deltoid (AD), the lateral head of triceps brachii (TB), and the latissimus dorsi (LD), in four tasks. The EMG signals were measured by a Pocket EMG System (BTS Company, Italy). All active channels were the same, and the measuring range was fitted to the subject (typically +/- 10mV). The analog signal was converted into a digital one with 16 bit sampling resolution and collected on measure unit.

Multidimensional movement analysis was made with the measuring system Smart-E (BTS, Italy) which consisted of six infrared cameras (120Hz) and a wireless module to measure muscle bioelectric activity (Pocket EMG). For further analysis, separate tension values of the 4 chosen muscles were considered during ascending (A), descending (D) and the whole movement (Sum).

After calculating the average values (x) and standard deviations (±SD), particular groups of presses with different loads were compared by ANOVA. The statistical analysis was directed at determining dependent variables differentiated by the independent variable. The statistical analyses were performed with the use of Statistica 9.1 software with a data mining module.

RESULTS

The results of ANOVA indicate significant differences in bioelectrical muscle activity in particular muscle groups, during either the ascending or descending phase of the lift under different external loads: TBSum ($F=14,43$, $p=0,001$), TBD ($F=11,52$, $p=0,001$), LDSum ($F=9,48$, $p=0,001$), LDD ($F=8,8$, $p=0,001$), TBA ($F=8,29$, $p=0,001$), LDA ($F=6,53$, $p=0,001$) and ADSum ($F=2,80$, $p=0,04$).
The pectoralis major showed no significant differences in muscle tension in relation to the lifted load (Fig 1). A verification of data (Levene's test) indicated the greatest increase of bioelectrical activity with increased external loads in the latissimus dorsi during the descending phase of movement ($F=0,006$, $p=0,011$).

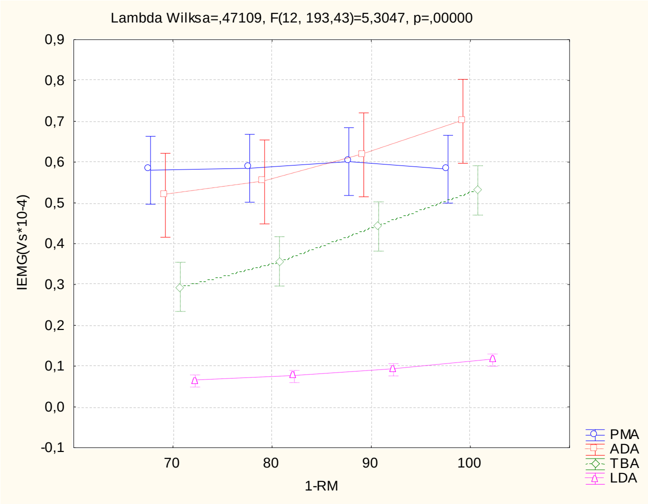

Fig 1. Average values of four anterior deltoid, pectoralis major, triceps brachii and latissimus dorsi, during the bench press with an external load of 70, 80, 90 and 100% 1-RM

DISCUSSION

During the descending phase of bench pressing the greatest muscle tension was observed in the pectoralis major. Smaller values were reached for the anterior deltoid, triceps brachii and latissimus dorsi in that order. For the descending phase of the lift the order of highest generated bioelectrical activity was: anterior deltoid, pectoralis major, triceps brachii and latissimus dorsi. It is interesting to notice that the muscle tension of pectoralis major during the ascending phase of bench pressing do not increase significantly with the rise in external load, yet the high values of bioelectrical activity classify this muscle as dominant. In contrary to other authors, our data indicates a significant increase in muscle tension of AD and TB with a rise in external load during the flat bench press (Santana et al. 2007; Barnett et al.). The latissimus dorsi, despite a significant rise in muscle tension which accompanies external load increase should not be classified as a dominant muscle group in bench pressing because of the relatively low bioelectrical muscle activity, what has been confirmed by other researchers (Santana et al. 2007; Van Den Tillaar and Ettema 2009) .

CONCLUSION

The changes in bioelectrical muscle activity during the flat bench press related to an increase in external load are caused by a rise in muscle tension of AD and TB, while the tension of PM remains almost unchanged.

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INDIVIDUAL STEP CHARACTERISTICS OF REPEATED EARLY ACCELERATION IN COLLEGIATE MEN SOCCER PLAYERS

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INTRODUCTION

Maximum acceleration from the standing start is important for athletes [1]. Although average step characteristics of step-length(SL), step-frequency(SF), contact time(Tc), and flight time (Tf) have been reported in relation to overall sprint time for sprinters, little is known how these factors are related to velocity of each step (Vstep) in the early phase of sprinting for field sports athletes. Furthermore, most studies analyzed the factors at the group level which might mask important coaching issue at individual level.

To optimize strength and power training to improve early acceleration in the field sport athletes, more precise data of step characteristics is needed.

The purpose of this study was to investigate the factors affecting the velocity at the each step of early acceleration for individual players.

METHODS

Ten collegiate men soccer players were tested for sprint from standing start over the first five steps of 10m repeatedly for 30times with 3.5 minutes rest period. Tc, Tf, and SL were measured by photo electric cell arrange dat 0.003m high and 0.01m interval on the floor with a sampling frequency of 1000Hzusing OptojumpNext (Microgate, Borzano, Italy).

SF and Vstep were calculated by the obtained value for every single step.

RESULTS

For all of the subjects as a group, significantly moderate to strong negative correlations were shown between Vstep and Tc at the 1st, 2nd,and 3rdstep ($r=-0.61$, -0.40, and -0.41, $p<0.01$), SF also showed significant moderate to strong positive correlation with Vstep at the 1st, 2nd, and 3rdstep($r=0.54$, 0.47, and 0.35, $p<0.01$).

In contrast, SL was strongly to very strongly related with Vstep at the 1st, 2nd, 3rd, 4thand 5thstep ($r=0.57$, 0.70, 0.62, 0.76, and 0.69, $p<0.01$) at a group level. However, at the individual level, SL was not necessarily related to Vstep at the all steps. Three subjects showed only one moderate to strong correlation at1stor 5thstep, and one subject showed no correlation between SL and Vstep at any step. On the contrary, SF was significantly correlated ($p<0.01$) very strongly($r>0.74$)to nearly perfectly ($r>0.96$)to Vstep at four to all five steps for nine of the ten subjects. SF was related to Tc and Tf to a similar extent ($r=-0.52$ and -0.47, $p<0.01$) at the group level. However, within individuals, SF was dependent on Tc or Tf more strongly than the other.

DISCUSSION

These data suggest that there are different determinants of Vstep at the individual level from the group level. Subjects with longer SL tended to gain faster Vstep when compared inter-individual subject level. However, at an inter-individual subject level, trials with higher SF appear to be more important than longer SL to gain faster Vstep. Theoretically, SF is decided by both Tc and Tf, or either or Tf, but the present data showed it depend a greater extent on Tc orTf differently with each subject.

CONCLUSION

Tc, Tf, SL, and SF should be measured individually in relation to Vstep to understand and improve early acceleration of the individual athletes.

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THE NEUROMUSCULAR AND INFLAMMATORY RESPONSES TO A MAXIMAL SPEED TRAINING SESSION IN RUGBY PLAYERS

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INTRODUCTION

Elite rugby players are required to perform several training sessions, with differing goals, during the week and often on the same day. To successfully accomplish this, training loads must be separated with sufficient recovery time to enable the athlete's neuromuscular system to meet the requirements of the next training session. While considerable research has examined the pattern of recovery following resistance training sessions (McCaulley, McBride et al. 2009), there is limited information on the recovery experienced after a maximal speed training session. Therefore the aim of this study was to assess neuromuscular and inflammatory response to a maximal speed training session over a 24 hour time period.

METHODS

Eighteen academy level rugby players (age 20.5 $\pm$ 1.2), with a minimum of two years training experience completed a speed training session comprising of 6 x 50m sprints with 5 minutes recovery between sprints. Lactate (La) and Creatine Kinase (CK) were determined prior to (PRE), ~15sec post (15sec post), 2 hours post (2hr post) and 24 hours post (24hr post) the sprint session. Peak power, jump height and average rate of force development (aRFD) were determined during both a squat jump (SJ) and countermovement jump (CMJ) at the same time points. Statistical analysis was carried out using a repeated measures one-way analysis of variance (ANOVA) on the various measures. Where a significant effect was observed paired comparisons were used in conjunction with Holm's Bonferroni method. Significance was set at $p \leq 0.05$. Ethical approval for the study was provided by the University of Ulster research ethics committee.

RESULTS

When compared to PRE CMJ peak power, CMJ jump height, SJ peak power and SJ jump height were found to be significantly lower 15 sec post (Table 1). However all had recovered by 2hr post. At 24hr post, CMJ jump height, CMJ aRFD, SJ Peak power, SJ aRFD and SJ jump height had again significantly declined vs. PRE (Table 1). La was significantly elevated 15sec post but not at any other time point, while CK was significantly elevated at all time points compared to PRE levels. SJ Peak power, SJ aRFD were significantly higher at 2hr post compared to 24hr post, while CK was significantly lower (Table 1).

Table 1: Squat jump (SJ), Countermovement jump (CMJ), Lactate and Creatine Kinase (CK) response to speed training. Data presented as mean ± SD.

	PRE	~15 sec post	2hr post	24h post
CMJ Jump Height (m)	0.40 ± 0.05	0.36 ± 0.06*	0.39 ± 0.05	0.38 ± 0.06*
CMJ Concentric Peak Power (w)	5193 ± 461	4963 ± 562*	5154 ± 503	5106 ± 508
CMJ aRFD (n/s)	4557 ± 1014	4333 ± 1282	4579 ± 1077	3891 ± 936*
SJ Jump Height (m)	0.33 ± 0.04	0.31 ± 0.05*	0.32 ± 0.05	0.31 ± 0.06*
SJ Peak Power (w)	5042 ± 479	4837 ± 574*	4964 ± 537	4742 ± 541*^
SJ aRFD (n/s)	5598 ± 902	5469 ± 1112	5637 ± 1027	4683 ± 978*^
CK (u l)	420 ± 360	514 ± 406*	615 ± 437*	990 ± 703*^
Lactate (mmol/l)	1.58 ± 1.06	10.6 ± 1.58*	2.06 ± 1.07	1.16 ± 0.35

* significant to 0.05 vs. PRE ; ^ significant to 0.05 vs. 2hr post

DISCUSSION

Functional neuromuscular performance underwent a complex recovery pattern with the initial declines experienced at ~15sec post recovered at 2hr of recovery 24hr post-secondary declines in several parameters had occurred. While a similar pattern has been demonstrated following various activities (Kuitunen, Avela et al. 2004; Cormack, Newton et al. 2008), this is the first study to demonstrate it post maximal speed training. When considered in the context of the La and CK responses we speculate that the initial decline in performance was as a result of the metabolic stress caused by the speed session, while the secondary decline was a response to the high degree of muscle damage experienced.

CONCLUSIONS

Given that recovery from speed training in rugby players follows a complex recovery pattern, it may be better to perform explosive activities requiring motor coordination following 2hr recovery compared to 24hr. Further research is required to examine the impact of a second training session (e.g. strength or power on the profile observed in the present study.

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THE EFFECTS OF TIME OF DAY ON PHYSICAL FITNESS PERFORMANCE IN COLLEGE-AGED MEN

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INTRODUCTION

Chronobiology can be defined as the study of rhythmic patterns in biological phenomena. Oscillatory fluctuations, called biological rhythms, occur in cells, tissues, organs, and more complex control ystems[4]. They are endogenous, arise within the organism, andipersist under constant environmental conditions. Although they may show a wide range of periods, circadian rhythms (from the Latin *Circa Diem* meaning about 24 hours) are the most extensively investigated. Rhythms are not imposed by the environment, but can be adjusted by exogenous synchronizing cues—for example, alternation of light and dark. However, the night day cycle has progressively lost some of its importance because of the invention of artificial light, which allows work by night [4]. The idea of a variation throughout the solar day of physiological and psychological variables is not recent. Daily variation in body temperature was first reported in 1778 [1]. These time-dependent variances are known as circadian rhythms. These psychophysiological functions exhibit maximum and minimum phases throughout the day. Many of these can have an effect on sports performance. Many physiologic processes follow a circadian rhythm of oscillation from peak to nadir throughout a 24-hour period (circa-about, dies-a day) [2,3].

MATERIALS AND METHODS

Subjects: Twelve male students (mean±SD; age 20.883±1.15 years; height 176.55±1.52 cm; body mass 73.91±1.71 kg) gave their informed consent and volunteered to participate in the study with the approval of the IA University, Shabestar branch Ethical Advisory Commission.

Procedures: The study was conducted in shabestar has a warm and moderately humid natural environment (the mean environmental temperature and humidity were 20.1C (±0.5C) and 65 % (±6%)outside). All the subjects had been acclimatized to this environment for years.

RESULTS

There were no significant main effects for time of day for aerobic power ($F(2, 27) = 1.367$, $p = 0.272$), speed ($F(2, 27) = 0.443$, $p = 0.647$), agility ($F(2, 27) = 2.314$, $p = 0.118$), average anaerobic alactic power ($F(2, 27) = 0.266$, $p = 0.769$), minimum anaerobic lactic power ($F(2,27) = 0.886$, $p = 0.424$), anaerobic alactic power($F(2, 27) = 5.307$, $p = 0.012$)and fatigue index($F(2, 27) = 0.703$, $p = 0.515$) (Table2).In contrast, there was a significant main effect for time of day for maximal anaerobic lactic power ($F(2, 27) = 8.079$, $p = 0.002$).

DISCUSSION

The aim of this study was to investigate the effects of time of day on some physical fitness factors in college-aged men**.** In the current study, the main findings during the times of testing indicated that aerobic power ,speed ,agility ,average anaerobic alactic power, minimum anaerobic lactic power, anaerobic alactic power and fatigue index showed no significant main effect for time of day. In conclusion, time of day showed no significant effect on the physical fitness variables observed in this study, thus indicating no diurnal effects. Future studies should include the examination of circadian rhythms and performance during undulating courses using each gradient period**.**

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MEASURING MUSCLE OXYGENATION WITH NEAR-INFRARED SPECTROSCOPY DURING BLOOD-FLOW RESTRICTED DYNAMIC EXERCISE

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INTRODUCTION

Low-load (20-50% of 1 RM) resistance training, combined with blood flow restriction to the working muscles (BFRE), has been reported as an effective alternative for gaining muscle mass [1, 8] or counteracting postoperative muscle atrophies [7]. Given that tissue hypoxia is likely an important trigger of muscle adaptation to BFRE training [6], accurate and relevant measurements of muscle oxygenation during free blood flow and BFRE are of vital importance for studying the phenomenon. Near–infrared spectroscopy (NIRS) is a widely used tool for evaluation of muscle hemoglobin and hence oxygen kinetics during exercise, for being non-invasive, reliable and easy to use [3, 5]. However, acquiring high quality signals during dynamic resistance exercise with either free blood flow or reduced blood flow and extracting physiologically relevant data with a *posthoc* analysis, remains a challenge. So far no standardized procedures for NIRS signal analyses have been endorsed. With the series of pilot experiments we elucidated some of the strengths and weaknesses of measuring oxygen kinetics of quadriceps femoris muscle by NIRS during normal and BFR exercise.

METHODS

Oxygen kinetics in v. lateralis femoris muscle during normal and BFR exercise were elucidated by NIRS in 10 healthy subjects (age 18-31 yrs.). Dynamic one-leg knee-extension exercise to volitional failure at 15% 1RM was performed once with free blood flow (Control test) and once with blood flow restriction (BFRE test). During the BFRE test, a pneumatic cuff on the proximal thigh was inflated to 230 mmHg. Repetitive weight lifting to volitional failure was performed at constant pace of 2 s per lifting cycle. The changes in signal traces, occurring due to either cuff inflation or initiation/cessation of exercise, were marked on raw signal traces, which served to denominate distinct phases of oxygen kinetics. The effectiveness of NIRS signal noise and exercise-induced artifacts removal by using either moving average of two lengths (2 and 10 s), or low-pass IIR digital filter at various cut-off frequencies (0.2, 0.1 and 0.05 Hz) was elucidated. Also, the accuracy of fitting the monoexponential model and logistic model to rapid exercise-induced changes in oxygenated ([O_2Hb]) and deoxygenated ([HHb]) hemoglobin concentrations at the onset of exercise (fast deoxygenation phase) were compared.

RESULTS

The monoexponential model did not provide the optimal fit for [O_2Hb] and [HHb] perturbations during the fast deoxygenation phase in 14 out of 20 measurements. An accurate fit was obtained with logistic model in all 20 cases. The least distortion of amplitude and introduction of time-shifts were obtained in all 20 cases by applying smoothening of the raw signal with 2-s moving average. In some cases during vascular occlusion, a sudden drop in absolute values of the NIRS signals at the start of muscle contraction was observed.

DISCUSSION

One of the fundamental issues when fitting a mathematical model to experimental data is how well the chosen model captures the actual nature of the observed physiological response. In case of muscle hemoglobin kinetics during moderate intensity exercise it can be assumed that it closely resembles the kinetics of oxygen (mVO_2), which are believed to be essentially equal to phase II of pulmonary oxygen kinetics (pVO_2) [11, 12] that is best represented by simple exponential function [4, 10]. From the physiological perspective, a time constant τ of monoexponantial model is a powerful tool to study responsiveness of the O_2 delivery/utilization system [12], which strongly influents muscle exercise tolerance and fatigue. However, the monoexponential model did not provide the optimal fit for [O_2Hb] and [HHb] perturbations during the fast deoxygenation phase in majority of our measurements. This challenges the validity and accuracy of pVO_2 for estimation of mVO_2 and the assumption of exponential nature of muscle oxygen kinetics at the initiation of exercise. Provided that the pressure of optodes to the skin surface due to fixation remains constant during muscle rest and muscle contractions, the cyclic intramuscular pressure fluctuations are directly reflected in deflection of NIRS signal. Smoothening of the signal with a 10-s moving average or low pass digital filtering at cut-off frequency of 0.1 Hz have been suggested appropriate to reduce the movement artifacts [9]. Or results show that the 10-s moving average is not optimal as it introduces a substantial temporal shift of trace deflection threshold and distorts timing of the response. As already demonstrated in patients with peripheral arterial disease [2], the application of ≤ 2-s moving average appears to be an optimal compromise between movement artifact reduction and distortion of essential signal parameters. In some cases, a sudden drop in absolute hemoglobin concentration values of the NIRS signals at the start of muscle contraction is observed during occlusion. The underlying mechanism has not been studied yet, but it may be that muscle edema due to incomplete arterial occlusion adds to the contraction-induced increase in intramuscular pressure.

CONCLUSIONS

Near-infrared spectroscopy is a powerful tool for measuring hemoglobin kinetics in the muscle and other soft tissues during exercise. A good preparation of the experiment and proper application of the sensor (optode) on the skin surface is critical for obtaining high quality signal, especially during dynamic exercise. Certain shifts and drifts of the NIRS signals can be observed and anticipated during measurement on contracting muscle, which can be minimized with adequate fixation of the optode and thoughtful *posthoc* signal analysis. Our results suggest that 2-s moving average should be used for optimal artifacts and noise removal. Oxygen kinetics during fast deoxygenation phase are better fitted with logistic than monoexponential model. Future mathematical modeling of the observed physiological responses of muscle hemoglobin kinetics to exercise should focus on more complex nonlinear models.

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ACUTE EFFECTS OF JUMPING AND SPRINTING ON HAMMER THROWING PERFORMANCE

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INTRODUCTION

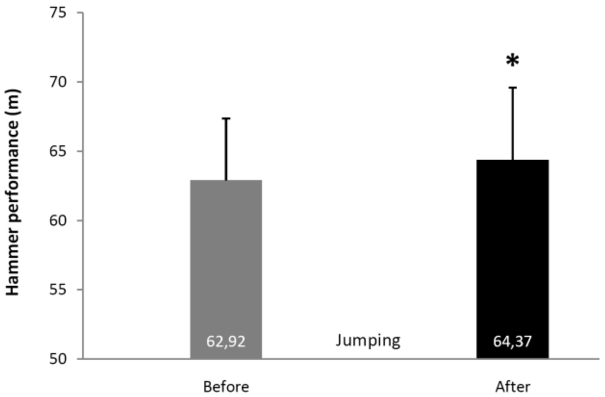
Recently, it was reported that 3 consecutive counter movement jumps or a bout of 20 m sprinting, induce an acute increase in shot put performance in experienced shot putters [1]. The purpose of the present study was to investigate the acute effect of counter movement jumping (CMJ) or sprinting on hammer throwing performance in experienced hammer throwers.

METHODS

Six well-trained hammer throwers, participated in the study. After 10 minutes of standard warm-up, they performed 3 hammer throwing attempts with maximum effort, with 1.5min interval. Three minutes later, they performed three maximal, consecutive CMJs. Immediately after the CMJs, they performed 3 hammer throwing attempts with maximum effort, separated with 1.5min interval. One week later, they carried out an identical protocol, but they performed a bout of 20 m sprinting instead of the CMJs, in order to potentiate shot put performance (interventions were counterbalanced). Paired t-test was used for statistical analysis.

RESULTS

Hammer throwing performance was significantly increased after CMJs (62.92 ± 4.4 m vs. 64.37 ± 5.21 m, P = 0.013) as well as after 20 m sprinting (64.87 ± 3.9 m vs. 65.27 ± 4.0 m, P = 0.047), although the increase in performance was not different between the two interventions (P = 0.214, ns, Figure 1).



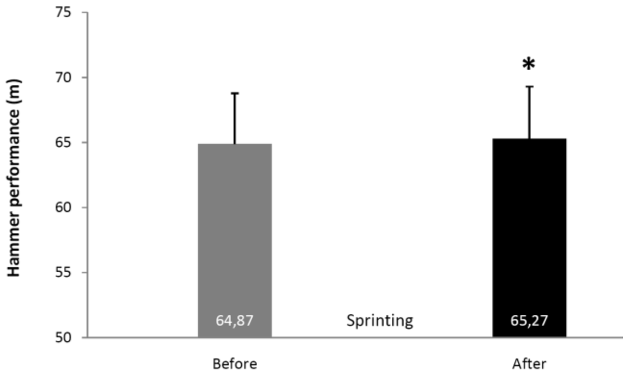


Figure 1. Peak hammer throwing performance in 6 well-trained hammer throwers before and after performing either 3 CMJ (left) or 20m sprinting (right) with maximum effort (* = P < 0.05).

DISCUSSION

The increase in hammer throwing performance might be attributed to the phenomenon of post activation potentiation [2], which is positively influenced by the percentage of type II muscle fibers. Indeed, hammer throwers possess a relatively high percentage of type II fibers [3].

CONCLUSION

These results suggest that performing 3 CMJs or one bout of 20 m sprint with maximum effort just before hammer throwing, may be a useful method for acute increases in performance in experienced hammer throwers.

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THE ANALYSIS OF THE RELATIONSHIP OF ONE REPETITION MAXIMUM (1RM) AND MAXIMUM POWER (P_{MAX}) IN SELECTED COMPLEX TRAINING EXERCISES IN WEIGHTLIFTING

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INTRODUCTION

To find appropriate indicators which would provide valid source information for ensuring the adequacy of load is a permanent problem. The knowledge of training variables [1] which may be accompanied by the specialties and a detailed description of the selected training method may seem like one of the limiting factors of the successfulness of the process. The comparison of the selected parameters of strength capabilities (1RM - one repetition maximum, Pmax - maximum value of average power in a diagnostic series) of special training methods in weightlifting can contribute to the scope of determinative information about their efficiency. An appropriate training impact in the meaning of intensification of load enables to use the potential of an athlete in the process of achieving the maximum athletic performance.

In common training practice, the intensity of load is determined by the percentage of 1RM or Pmax. Most of coaches use general recommendations which indicate that the weight at which Pmax is achieved is approximately between 50-60(70)% of 1RM. In fact, however, it is known that such generalization is inaccurate and may reduce the training effect significantly. The method should be highly intraindividual in nature, it should be based on completion of the diagnostic series within which 1RM and the position of weight with Pmax is determined by using the diagnostic equipment (through which we are able to measure the parameters of performance). It is clear that the differences will involve the exercises focused more on strength without highlighting the speed of performance and technically demanding exercises with speed attributes. Rough categorization of exercises is informative for common practice, however, still insufficient for a perfect quantization of load. The description of the selected exercises well-known in fitness training remains the subject of examination in the majority of sports in terms of wider scale of parameters of power capabilities. The methodology of the examination must also solve the dilemma of a possible phasing of the movement because of the unequal course of the operating forces. The aim of the pilot study was to examine relationship of 1RM and Pmax in selected complex training exercises and possible differences of the selected parameters in relation to the nature of the exercises studied.

METHODS

A male national-level weightlifter with adequate length of sports practice, level of performance, technical maturity volunteered for the study. Multi-joint complex exercises were selected which are also competitive disciplines and special training methods in weightlifting. The common characteristics of these exercises are high demands laid upon coordination of activity of individual body segments and uneven course of speed and power. The exercises chosen (n=8) were divided into a category of special technical exercises (n=4) and special strength exercises (n=4). When verifying the hypothesis which assumed a different relationship between performance and one repetition maximum depending on the nature of selected exercises, we used the diagnostic equipment designed for measuring the mechanical muscle performance whose main part is a sensor of speed and movement. After analog-digital conversion, the measured signals are fed into a computer, then it is possible to calculate and display the basic biomechanical parameters applicable to muscle contraction by means of the software. With a sufficient time interval we carried out the diagnostic series in selected special tests with maximum effort from the initial weight (20 kg) after 1RM. When editing the obtained data, we focused on the concentric phase, in technical disciplines up to the maximum height of the lift of the barbell. Such designed diagnostic curves enabled us to assess the position of the weight with the maximum average power (Pmax) in relation to 1RM. At the same time, we were able to create the Pmax zones (90% of Pmax, 95% max) which represent a possible alternative for determining the load in management of the training process (with respect to the current condition of an athlete and training principles relating to the training with maximum effort). We completed three repeated measurements in an 8-week period to confirm the findings, so respecting the fact that the subject was involved in a continuous training process.

RESULTS

The results of the measurements confirm the assumption that the relationship between the parameters studied (Pmax, 1RM) is not stable. In addition to the effect of a long-term specialized activity, it changes also according to the nature of a selected exercise. Special technical exercises (including competition disciplines) whose successfulness is subject to high level of technical performance, certain minimal height of the equipment in the final phase of the lift and the speed of movement move the maximum performance closer to 1RM. In technical disciplines, the subject achieved his Pmax in the range of 89.7-98.3% of the corresponding 1RM. (Fig. 1). In the case of special strength exercises, where strength dispositions of an athlete rather than speed and height of the lift are important for realisation, the subject achieved his Pmax in the range of 64.0-72.9% from 1RM registered (fig. 2). The results of our findings correspond to the findings of the authors [3] and contribute to the scope of resources for choosing the size of the resistance. According to the authors, the percentage of the selected parameter of strength capabilities changes according to the indicator of maximal power. Despite the calculation of Pmax in relation to maximum isometric power (25 - 40%), a discrepancy arises in determining the relationship of maximum isometric power and maximum dynamic power. The generally valid data (80-85%) changed rapidly depending on the distance of the movement of equipment and athlete (in weightlifting disciplines, 1RM at the level less than 61% in relation to maximum isometric power in three key moments of the movement chain were calculated).

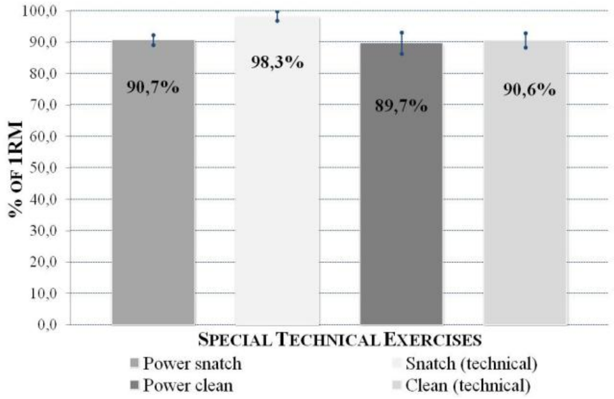

Fig. 1: The relationship of the weight at the level of Pmax to 1RM in special technical exercises

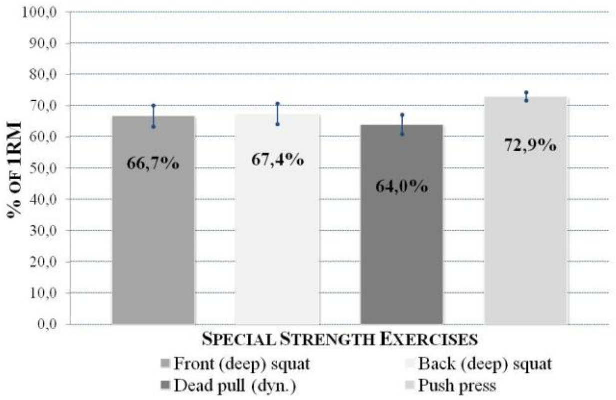

Fig. 2: The relationship of the weight at the level of Pmax to 1RM in special strength exercises

DISCUSSION

We present the results shown as a form of pre-study. Further on we carry out a research on a group of athletes who have experience with the selected methods of measurement and are able to work consistently with maximum effort throughout the entire diagnostic series. We recommend to consider the possibility to analyse the training at the level of Pmax (in the zone 90%, or in the zone 95%) and apply the changes registered to the extent of representation of selected exercises during the experiment, namely to the total number of generated Watts in a given discipline for the period studied, or to the average power for an attempt in a given series.

CONCLUSIONS

The results showed clear differences of the two distinct types of exercises on Pmax and 1RM parameters. In exercises more closely related to the weightlifting performance, the subject achieved his Pmax in the range from 89.7 to 98.3% of 1RM. In case of more general, maximum strength-based exercises, the subject could performe the highest Pmax with lower relative load ranging from 64.0 to 72.9% from 1RM registered.

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BIOMECHANICAL COMPARISON OF THE DEADLDLIFT AND POWER CLEAN PERFORMED EXPLOSIVELY WITH SUB-MAXIMUM LOADS

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INTRODUCTION

Currently, one of the main physical training practices recommended for athletes to develop muscular power and athleticism is the performance of explosive resistance training[1]. The majority of researchers in the field of strength and conditioning have suggested that the practice of explosive resistance training should be restricted to the use of plyometric, ballistic and Weightlifting exercises such as the clean, snatch and their variations[1,2]. Traditional resistance exercises such as the bench press, deadlift and squat are considered inappropriate due to low power outputs and large decelerations which are reported to occur when these exercises are performed explosively with sub-maximum loads[3,]. However, the initial research conducted on the biomechanical stimulus of traditional resistance exercises was mainly limited to the bench press and featured only a narrow range of mechanical variables. More recent studies have demonstrated that well trained athletes with experience in performing explosive resistance training with traditional resistance exercises can develop large power outputs and adopt movement strategies which enable acceleration for the majority of the movement[4]. It was the purpose of this study to compare the biomechanical stimulus created during fast velocity repetitions with a traditional resistance exercise and the power clean which is considered one of the best exercises for development of muscular power[5]. A three dimensional rigid body model was employed to analyse both internal and external mechanical variables.

METHODS

A cross-sectional, repeated measures design was used to quantify and compare the kinematics and kinetics of the deadlift and power clean when attempting to perform maximum velocity repetitions across a range of sub-maximum loads. The deadlift was selected as it is one of the most commonly performed traditional resistance exercises and is most outwardly similar to the power clean, including the omission of a stretch shortening cycle action. The participants included twelve strongman competitors (age: 27.4 ± 4.5 yr; stature: 182.5 ± 3.3 cm; mass: 112.1 ± 19.2 kg; resistance training experience: 11.7 ± 4.4 yr) with a minimum of three years experience in performing the deadlift and power clean. Data were collected for each participant over two sessions separated by one week. Session one was performed in the gymnasium and involved one-repetition maximum (1RM) testing in the deadlift and power clean. Session two was performed in the laboratory where participants performed maximum velocity repetitions with 40, 60 and 80% of their recorded 1RM. Kinematics and kinetics were analysed during the second session with each repetition performed on piezoelectric force platforms (Kistler, Type 9281B Kistler Instruments, Winterthur, Switzerland) in a motion capture volume defined by eight optoelectronic cameras (Vicon MX, Vicon Motion Systems, Oxford, UK). A rigid lower body model was used to calculate internal kinematics and kinetics at the hip knee and ankle[6]. Standard external variables were calculated using the ground-reaction force data and positional information obtained from markers affixed to the external resistance. Potential differences were analysed using a 2x3 (exercise x load) repeated measures ANOVA. Significant main effects were further analyzed with Bonferroni adjusted pair-wise comparisons. Statistical significance was accepted at $P < 0.05$.

RESULTS

The participants were able to lift twice as much in the deadlift as compared with the power clean (1RM deadlift: 280.9 ± 48.8 kg; 1RM power clean: 139.2 ± 19.4 kg). The greater absolute loads lifted during the deadlift resulted in significant main effects for the ground-reaction force (GRF) and velocity as measured from the time derivative of the barbell's position. Increases in force obtained with the deadlift were considerably less than the reductions experienced in velocity. The overall profile of the GRF exhibited substantial differences between exercises. Force values increased rapidly over the initial phase of the deadlift and were maintained at a high level until close to the end of the movement. In contrast, during the power clean force values dropped to zero after the first stage of the movement before increasing rapidly to a much larger second peak. The bimodal force profile developed during the power clean resulted in significantly greater peak rate of force development (RFD) values. Data from the rigid body model showed that joint velocities for the hip, knee and ankle were similar for both exercises. Net-joint moments developed at the hip and ankle were significantly greater during the deadlift, with lower values in comparison to the power clean developed at the knee (Table 1). The combination of these differences resulted in mixed results for the joint power values with large values obtained for both exercises (Table 1).

Table 1 Comparison of peak joint moments and peak joint powers (mean ± SD)

Load	Variable	Deadlift			Power Clean		
		Hip	Knee	Ankle	Hip	Knee	Ankle
40%	PJM (Nm^{-1})	251 ± 30*	41 ± 20	174 ± 32*	210 ± 22	118 ± 36*	142 ± 30
1RM	PJP (W)	764± 184	147 ± 116	512 ± 185*	693 ± 195	241 ± 128*	217 ± 75
60%	PJM (Nm^{-1})	299 ± 34*	37 ± 23	204 ± 38*	224 ± 27	132 ± 38*	164 ± 29
1RM	PJP (W)	620 ± 153	149 ± 92	460± 200	750 ± 212	264 ± 89	369 ± 140
80%	PJM (Nm^{-1})	328 ± 38*	10 ± 15	205 ± 23	241 ± 30	154 ± 41*	187 ± 33
1RM	PJP (W)	423± 121	68 ± 16	164± 89*	685 ± 174*	300.9 ± 190*	501 ± 190*

PJM = peak joint moment, PJP = Peak joint power. *Significantly greater than corresponding condition ($p<0.05$).

DISCUSSION

The results of the study show that in addition to a range of significant biomechanical differences between the deadlift and power clean there are also important similarities which have not previously been acknowledged. As expected, the heavier absolute loads used with the deadlift resulted in greater force production and reduced velocity of the barbell. Additionally, GRF-time curves illustrated that the occurrence of the double knee bend[5] during the power clean created peak RFD values which were significantly greater than those produced during the deadlift. In contrast, the internal variables calculated using the rigid body model revealed that maximum joint angular velocities and joint power values were similar for both exercises. As a result, previous suggestions that traditional resistance exercises are too slow or do not produce adequate power to be effective in training are not supported. For the internal variables measured significant differences were noted at the knee joint, which again is likely to have been caused by the occurrence of the double knee bend during the power clean.

CONCLUSIONS

The results of the study suggest that previous recommendations not to include traditional resistance exercises such as the deadlift with explosive resistance training may be unwarranted.

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KINETIC AND ELECTROMYOGRAPHIC COMPARISON OF THE BACK SQUAT AND OVERHEAD SQUAT

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INTRODUCTION

The back squat is recognised as one of the most effective resistance exercises to develop the musculature of the lower-body[1]. Due to the popularity of the exercise a number of variations have been created with the belief that each presents an effective but somewhat distinct biomechanical and physiological stimulus[2]. The overhead squat is commonly prescribed for athletes based on the assumption that the exercise maintains many of the advantages of the back squat whilst creating greater activation of the core musculature[2]. The assumed increased activation of the core musculature during the overhead squat is thought to be caused by the unique positioning of the external resistance which leads to increased demand to maintain balance and correct postural perturbations[3]. However, despite widespread acceptance of the effectiveness of the overhead squat to recruit and provide an appropriate training stimulus for the core musculature, there have been no experimental studies conducted to test these hypotheses. Additionally, it unknown whether lighter resistances used during the overhead squat will affect important biomechanical variables such as force and power which will have implications for subsequent adaptations. Therefore, the aim of this investigation was to compare the kinetic and electromyographic stimulus of the back squat and overhead squat. A selection of popular isolation exercises used to recruit the core musculature was also included to provide additional comparisons.

METHODS

Fourteen elite male rugby union athletes (age: 26 ± 5 yr; stature: 182.5 ± 12.5 cm; mass: 90.5 ± 17.5 kg; 3RM back squat: 147.5 ± 27.5 kg; 3RM front squat: 77.5 ± 17.5 kg) participated in this study. Data were collected for each participant over two sessions separated by one week. The first session comprised 3RM testing in the back squat and overhead squat in a randomised order. During the second session participants performed maximum velocity repetitions in the back squat and overhead squat with 75 and 90% of their respective 3RM loads. Repetitions were performed on a force platform with surface EMG signals recorded from eight muscles including the anterior deltoid (AD), rectus abdominus (RA), external oblique (EO), erector spinae (ES), gluteus maximus (GM), vastus lateralis (VL), biceps femoris (BF), and gastrocnemius (GA). The amplified myoelectric signals were full wave rectified and filtered (6-pole Butterworth, band pass filter 10-500 Hz). The integrated values were calculated and then averaged over the concentric partition of the repetition. Values obtained were normalised relative to the average integrated EMG recorded during maximum voluntary isometric contractions (MVIC's) recorded for each muscle and then expressed as a percentage. A forward-dynamics approach was used with the force platform data to calculate the velocity and power of the athlete and external load system. Once the squat repetitions were completed each participant then performed four core exercises comprising the front plank (FP), side plank (SP), swiss ball ski tuck (SkiTu) and straight-leg situp (Situp). A general linear model with repeated measures and Bonferroni *post hoc* tests were used to determine significant differences.

RESULTS

The results showed that when the athletes switched from the back squat to the overhead squat there was a significant increase in activity of the AD, RA and EO; and a significant decrease in activity of the ES, GM, VL, BF and GA (Table 1). Comparisons between the activity of the core musculature during both squatting movements and popular isolation exercises were made using data collected during the 90% 3RM trials (Figure 1). Significantly greater muscular activity was recorded for the RA and EO in the front plank, side plank and straight-leg situp compared with both squatting exercises. In contrast, significantly greater muscular activity was recorded for the ES in both squatting movements in comparison to each of the isolation exercises. Analyses from the force platform data revealed that significantly greater force and power values were produced during the back squat (Table 2).

Table 1: Normalized (%MVIC) EMG comparisons (mean±SD) of back squats and overhead squats

Load	Muscle	Back Squat	Overhead Squat
	AD	17.5 ± 9.8%	52.1 ± 19.3%*
	RA	10.1 ± 4.1%	9.9 ± 4.6%
75%	EO	24.4 ± 10.2%*	21.8 ± 7.5%
3RM	ES	83.8 ± 21.4%*	75.9 ± 26.6%
	GM	85.7 ± 45.2%*	66.9 ± 34.1%
	VL	91.7 ± 26.6%	87.5 ± 25.4%
	BF	66.5 ± 29.1%*	56.0 ± 24.4%
	GA	56.5 ± 35.9%*	44.9 ± 22.9%
	AD	25.1 ± 14.7%	59.7 ± 18.7%*
	RA	10.7 ± 4.1%	11.4 ± 4.6%
90%	EO	22.5 ± 11.0%	27.2 ± 9.2%
3RM	ES	94.7 ± 20.8%*	68.7 ± 22.5%
	GM	92.7 ± 50.0%*	53.5 ± 32.1%
	VL	99.2 ± 30.6%*	82.3 ± 24.1%
	BF	71.1 ± 27.6%*	44.9 ± 26.8%
	GA	62.5 ± 38.4%	45.2 ± 23.7%

***Significantly greater than corresponding condition**

Figure 1: Squat and isolation exercise comparison

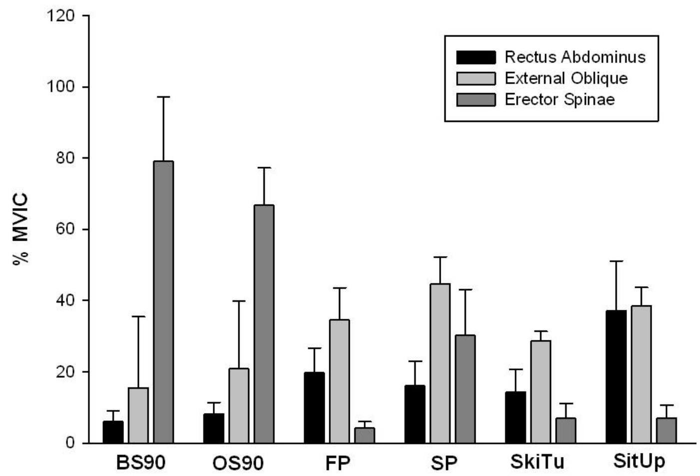

Table 2: Kinetic comparisons (mean±SD) of overhead squats (OS) and back squats (BS)

	Force	Power
OS 75%	1807.3 ± 214.5	1601.2 ± 410.1
OS 90%	1836.3 ± 376.3	1587.8 ± 571.4
BS 75%	2434.8 ± 272.2*	1981.4 ± 563.4*
BS 90%	2577.5 ± 380.1*	1955.2 ± 498.4*

***Significantly greater than corresponding condition**

DISCUSSION

The results of the present study demonstrate that the kinetic and electromyographic stimulus created when performing the overhead squat is significantly different from that created when performing the back squat. In support of anecdotal claims, the results demonstrate that significantly greater muscle activation occurs in the anterior core muscles (RA and EO) during performance of the overhead squat in comparison with the back squat. However, the increases in RA and EO activity when performing the overhead squat were shown to be low in magnitude and, importantly, substantially less than that which could be developed during exercises commonly used to isolate the core musculature. In addition, muscular activity of the posterior of the core muscles (ES) was shown to be significantly greater during performance of the back squat. This difference was most likely caused by variation in the position of the external load relative to the joint centres of the lumbar spine during both exercises. The kinetic results showed that force and power production is significantly reduced when switching from the back squat to the overhead squat which was also reflected in reduced EMG activity of the lower body muscles. Based on these restricted results it is not clear what advantages may be gained from performing the overhead squat instead of the back squat. Future research may wish to consider factors such as joint mobility and strengthening of the shoulder girdle as potential strong points of the overhead squat.

CONCLUSIONS

The results of the study suggest that substituting the overhead squat for the back squat is unlikely to confer any advantages and is more likely to limit training related adaptations.

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BENCH PRESSING IN LIGHT OF REGRESSION MODELS

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INTRODUCTION

Flat bench pressing is one of the most popular strength exercise, performed by athletes of different sport disciplines. At the same time bench pressing is part of powerlifting and a sport discipline on its own. To underline the importance of bench pressing, one must state that World Championships are held each year in both sport disciplines. To analyze particular motor activities, precise data is necessary related to basic variables. Recently regression models are extensively applied in sports, which allow to indicate a task predictor, and to describe the optimal sequence of motor activities and predict the final result. An additional objective of regression models in sport is a determination of discriminants in a specific sport discipline.

METHODS

Twenty international level athletes took part in this research. All subjects had at least 5 years of weight lifting experience prior to the study.

Exercise protocol

After a general warm-up, each subject performed a specific warm-up that consisted of two sets of 6 repetitions of the flat bench press. The 1-RM value was used to determine the intensities of particular bouts that were applied during the testing session and later to create the regression model. The session included four sets of one repetition of the flat bench press with 70, 80, 90, and 100 % of 1RM. During these tests the discrimination analysis was used to determine the best discriminants for each load respectively.

Electromyography

Two disposable surface electrodes were placed 2 cm apart over the motor points of the pectoralis major (PM) the anterior deltoid (AD), the lateral head of triceps brachii (TB), and the latissimus dorsi (LD) parallel to the muscle's fiber direction. The EMG signals were measured by a Pocket EMG System (BTS Company, Italy).

Data collection

Measurements identified 42 variables. To determine the optimal set of predictors, vector R0 was determined for the explanatory variables and vector R1 for the correlations generated by vector R0 for variables showing a significant correlation with the explained variable Y – sport result. The analysis determined nine parameters as the optimal set of variables.

Statistical analysis

Dependency between vectors R0 and R1 were obtained by calculating the Pearson correlation coefficients. The optimal set of variables was used for model construction. The regression and discrimination models were used in the process of modeling. Models and adequate functions identified predictors and discriminants of the bench press. The level of significance for all analyses was set at $p \leq .05$.

RESULTS

The analysis of regression defined a function, determined the model and bench press (BP) predictors:

Y(SportResult)=281.8–209.4*VmaxD+780.5AminA+0.3*ZA–25.2*AmaxA–267.2*VminA–112.7*TBD–1.4*XA+0.2*YA–32.3*TD

Where: **VmaxD -** maximal velocity during the descending phase, **AminA -** minimal acceleration during the ascending phase, **ZA -** anteroposterior displacement during the ascending phase, **AmaxA -** maximal acceleration during the ascending phase, **VminA -** minimal velocity during the descending phase, **TBD -**

Triceps Brachi during descending phase, **XA -** lateral displacement during the ascending phase, **YA -** vertical displacement during the ascending phase, **TD** – time of descending phase.

The built model incorporating nine parameters was found to explain 81% (R^2=0, 81) of the dependent variable's variability, thus demonstrating its goodness of fit, with F=9,13 and p<0,001.

The discrimination model defined the following discriminants of Y (Sport Result): Time of ascending phase (TA) F=13.75, p=0001; Triceps Brachi during ascending phase (TBA) F=12.81, p=0, 0001; Maximal velocity of the bar during the ascending phase (VmaxA) F=8.73, p=0005; AminA F=5.61, p=001 (Table 1).

Table 2. Discrimination statistics of model for Y- sport result (BP)

Variable	Lambda Wilksa	Sub. Wilksa	F	*p*
TA	0,253	0,636	13,750	0,000
TBA	0,247	0,652	12,815	0,000
VmaxA	0,220	0,733	8,731	0,000
AminA	0,199	0,810	5,615	0,002

p<0.05

DISCUSSION

The main objective of the research was to determine predictors and discriminants of bench pressing. The regression model identified the following predictors as most important. Maximal velocity of the bar during the descending phase (b=1.3), Maximal acceleration of the bar during the ascending phase (b=0.8) and bar descending time (b=0.7). The results of the analysis are in accordance with the conclusions of Reynolds et al. (2006) and Requena et al. (2005). Unfortunately there is little data about the application of regression and discrimination models in powerlifling, thus it is difficult to compare our results to others. The discrimination model identified the following discriminants as most important in bench pressing: Lifting time (L.Wilksa=0.25) and Triceps Brachii bioelectrical activity (L.Wilksa=0.24). The signs in VmaxD, AmaxA and TD indicate clearly that in order to improve the bench press result (1RM), one must reduce bar descending velocity (m/s), decrease the ascending acceleration of the bar (m/s^2), while simultaneously decreasing descending time (s). These results are in accordance with those of Lagally et al. (2004) as well as Van den Tillaar and Ettema (2009).

CONCLUSION

The descending phase of bench pressing should be performed without sudden changes in velocity of the bar (Vmax). This phase should be fairly short while the (TD) and the bioelectrical activity of the triceps brachii should be minimal. The ascending phase of the bench press should be well balanced in relation to bar acceleration and velocity.

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ACUTE METABOLIC AND MECHANICAL RESPONSE TO RESISTANCE TRAINING PERFORMED AT MAXIMAL INTENDED VS. HALF-MAXIMAL LIFTING VELOCITY IN THE SQUAT EXERCISE

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INTRODUCTION

One variable whose role has not been sufficiently investigated when designing resistance training (RT) programs is movement velocity [1]. We have recently shown that mean velocity can be used to adequately estimate loading intensity (%1RM) in the bench press [2] and that velocity loss allows to objectively quantify neuromuscular fatigue during RT [3]. This study aimed to compare the acute metabolic and mechanical response of squat (SQ) exercise protocols that only differed in the actual lifting velocity of every repetition performed: maximal intended velocity (MaxV) versus haf-maximal velocity (HalfV).

METHODS

Ten moderately strength-trained male adults (age 29.3 ± 5.1 yr, height 178.7 ± 9.0 cm, body mass 78.5 ± 9.1 kg, body fat 12.0 ± 3.1 %, 1RM full SQ 90.7 ± 17.5 kg, counter-movement –CMJ– height 36.6 ± 6.0 cm), undertook a total of six RT sessions in the SQ exercise (two per week) during a 3-wk period in the following order: 3 x 8 rep with 60% RM at MaxV (~0.98 m/s), 3 x 8 rep with 60% RM at HalfV (~0.49 m/s), 3 x 6 rep with 70% RM at MaxV (~0.82 m/s), 3 x 6 rep with 70% RM at HalfV (~0.41 m/s), 3 x 3 rep with 80% RM at MaxV (~0.68 m/s), 3 x 3 rep with 80% RM at HalfV (~0.34 m/s); with 3-min inter-set rests. Sessions were performed at the same time of day (± 1 h) for each subject under the same environmental conditions (20ºC and 60% humidity) and separated by 48-72 h. Subjects were not allowed to take part in any other RT session or strenuous physical activity during the study. A standardized warm-up protocol was strictly followed, always using the same absolute loads for each subject. Whole capillary blood samples were collected at rest as well as 1-min (lactate, ammonia) and 30-min post-exercise (uric acid). Percent change in CMJ height pre-post exercise was examined as a measure of neuromuscular fatigue. Three CMJs intersped by 15 s pauses were performed before (at the end of the warm-up) and ~75 s following each exercise protocol (after blood sampling). The outcome variable used for all velocity measurements was mean propulsive velocity (MPV) [4]. The SQ exercise was performed in a Smith machine according to the protocol described elsewhere [3]. MPV was monitored in each session and auditory feedback provided in real time for every repetition by means of a linear velocity transducer sampling at 1,000 Hz and custom software (T-Force System, Ergotech, Spain). Subjects received verbal cues to perform each repetition either at MaxV or at HalfV according to the corresponding session. The Lactate Pro LT-1710 (Arkray, Kyoto, Japan) portable analyzer was used for lactate measurements. Ammonia was measured using PocketChem BA PA-4130 (Menarini Diagnostics, Italy). For uric acid determinations, a Reflotron (Boehringer Mannheim, Germany) analyzer was used. A t-test for paired samples was used to compare mean differences between the two conditions (MaxV vs. HalfV). Values are reported as mean ± SD. Effect sizes were calculated using *Hedge*'s g as follows: g = (mean MaxV – mean HalfV)/combined SD. Statistical significance was accepted at $P < 0.05$.

RESULTS

Both blood lactate and ammonia tended to be higher when repetitions were performed at maximal intended velocity (MaxV) compared to when they were performed intentionally slower at half-velocity (HalfV) (Fig. 1 and 2). However blood uric acid levels 30-min post-exercise were not different between the two exercise conditions for any exercise session and remained at typical resting values for this group of young male adults (313 ± 66 µmol/L). Significantly higher reductions pre-post exercise in CMJ height were found for the MaxV compared to the HalfV condition following the 3x8 with 60% RM and 3x6 with 70% RM exercise sessions. In the 3x3 with 80% RM session the reduction in CMJ height did not reach statistical significance but there was clearly a tendency towards greater loss for the MaxV condition (Table 1).

Figure 1

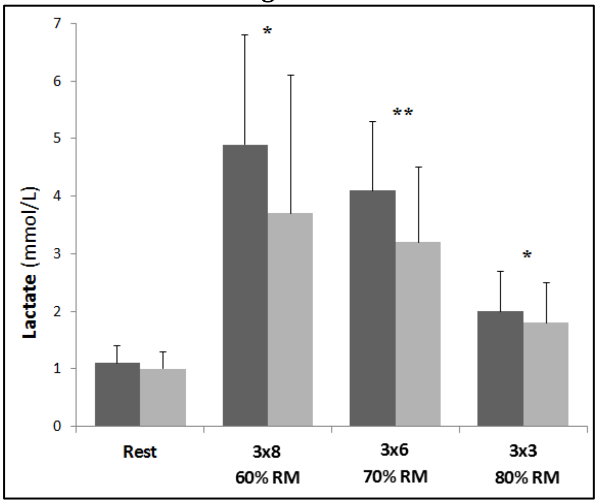
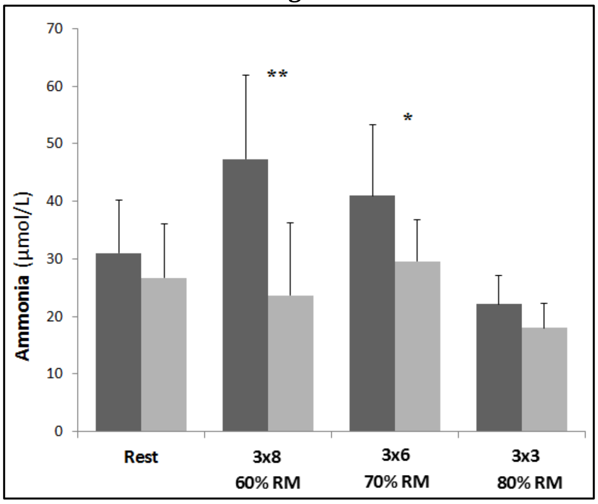


Figure 2



Significant differences: * $P < 0.05$, ** $P < 0.01$

Table 1. Percent change in CMJ height pre–post exercise following each RT protocol.

	MaxV	**HalfV**	**P**	**Effect Size**
3x8 with 60% RM	14 ± 5 %	9 ± 4 %	< 0.01	1.10
3x6 with 70% RM	14 ± 4 %	11 ± 5 %	< 0.01	0.66
3x3 with 80% RM	10 ± 4 %	8 ± 5 %	NS	0.44

DISCUSSION

Metabolic stress and neuromuscular fatigue tend to be higher when each repetition of a training set is performed at maximal intended velocity compared to half-maximal velocity. From the results of this study, it seems evident that both faster movement velocities and greater number of repetitions performed during resistance exercise cause higher lactate values, indicating that any of these factors contribute to an increased rate of glycolysis in muscle fibers. Maximal intended lifting velocities demand the recruitment of fast motor units which produce higher lactate levels. Our results regarding higher blood lactate values for fast (MaxV) compared to slow (HalfV) lifting velocities contradict those of a somewhat related study by Mazzetti et al. [5] who found greater blood lactate for ‘slow’ compared to ‘explosive’ contractions in a squat-machine exercise, despite ‘explosive’ contractions inducing greater increases in the rate of energy expenditure. However, the results of both studies are not directly comparable due to several important methodological differences in the exercise protocols and study design.

CONCLUSION

Movement velocity is a fundamental component of exercise intensity during RT. Future experimental research should further explore the effects of training with maximal vs. submaximal intended velocity on neuromuscular performance.

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ACUTE SERUM MONOAMINE RESPONSES TO DIFFERENT TYPES OF EXERCISE IN BASKETBALL PLAYERS

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INTRODUCTION

In response to identical relative work load, adrenaline release from adrenal medulla is higher in endurance trained athletes vs. sedentary individuals. This supposedly is a result of long term adaptation of the endocrine gland to physical training (Kjaer 1998). However, there is no data on monoamines response to different exercise types in athletes.

METHODS

Nine well-trained male basketball players, aged 22.3 ± 2.9 yrs, with training history of 8.6 ± 2.3 years (mean ± SD) took part in this study. Body height and mass of the tested athletes were 197.1 ± 4.3 cm and 91.6 ± 14.3 kg, respectively. The study was performed during the pre-competitive period of the annual training cycle, after 6 weeks of general and specific conditioning. During this period, the players trained 8 times per week, each session lasting about 2h.

The exercises (isometric, concentric and eccentric, of moderate intensity each) were performed in randomized order, with two-day intervals. Prior to each exercise, the participants performed a standard 20-min warm-up which consisted of jogging and stretching. Antecubital fasting venous blood samples were collected between 8:00 and 10.00 AM in vacutainer tubes 10-15 min prior to and immediately after completion of the exercise. Serum adrenaline (A), noradrenaline (NA), dopamine (DA) DA metabolites (3,4- dihydroxyphenylacetic acid, DOPAC, and homovanillic acid, HVA) as well as serotonin (5-HT) and its metabolite 5-hydroxyindoleacetic acid (5-HIAA) were assayed using HPLC with electrochemical detection (Coulochem III model 520; ESSA, Copenhagen, Denmark).

RESULTS

None of the tested exercises significantly modified serum NA, 5-HIAA, or A. The eccentric exercise significantly elevated serum DA (+83%) and a similar tendency was found for the concentric exercise (+25%). Interestingly, the concentric exercise significantly and markedly elevated (+91%) serum HVA, but not serum DOPAC (+11%), whereas the reverse was true for the isometric exercise (-16% and +175%, respectively). The concentric exercise also significantly elevated serum 5-HT (+42%), whereas a reverse tendency was found for the isometric and eccentric exercise (-34% and -19%, respectively).

CONCLUSIONS

Various exercise types exert differing effects on circulating monoamines and their metabolite levels (mostly those of DA, DOPAC and HVA) in well-trained athletes. The role of different (central vs. peripheral; see Alfredsson et al. 1988) sources of these metabolites in the observed effects needs to be clarified.

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ACUTE EFFECT OF ANTAGONIST STATIC STRETCHING ON ELECTROMYOGRAPHIC SIGNAL AND AGONIST REPETITION PERFORMANCE

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INTRODUCTION

Static stretching (SS) has been commonly applied as part of warming up before resistance training (RT) in order to increase range of motion, potentially reducing the risk of injury, as well as improving performance [1]. Recently, the application of SS before exercises has been questioned [2]. Some authors observed negative effects on strength performance after SS [3, 4]. Thus, several studies examined the effects of SS applied on agonists musculature, on the other hand, there is no evidences about the potentials effects of antagonist SS on agonists performance. Recently, Sandberg et al. [5] applied the SS on antagonist muscles and observed significant improvement in vertical jump performance, possibly indicating that the neural inhibition of antagonists improves the agonist activation and performance. It has been suggest that the antagonist pre-activation could promote a reduction in antagonist coactivation and increase neural activities of agonists resulting in improvement on muscle performance [6]. Although, there is no enough evidences in the literature to support this hypothesis [7]. Therefore, the purpose of this study was to investigate the acute effects of antagonist SS on agonist and antagonist muscle activation and the number of repetitions performed by agonists.

METHOD

Fifteen recreationally trained subjects (22.4 ± 1.1 years; 76.6 ± 7kg; 175 ± 5.5cm; 12.3 ± 2% body fat) with previous RT experience (3.5 ± 1.2 years) participated in this study. All subject had mean of 60-minute session per week , using 1-to 2-minute rest interval between sets and exercises and performed at least 4 training sessions per week. A week before testing, the loads of 10 maximum repetitions (RM) were determined in the seated row with wide grip exercise (SR) on 2 nonconsecutive days [8]. During SR exercise the participants were instructed to maintain a constant velocity of 2 seconds for phase (concentric and eccentric) controlled by metronome. The experimental protocols were conducted in two sessions with an interval of 48 hours. Traditional Protocol (TP): participants performed 1 set of SR until concentric failure with 10RM load. Antagonist Stretching (AS): Participants performed 1 set of 40 seconds (1 x 40") of SS on shoulders adductors muscles immediately followed by 1 set of SR until concentric failure with 10RM load. The SS of shoulders adductors was conducted according to Franco et al. [4]. In both protocols the number of repetitions completed without error in the technique was recorded and the electromyographic (EMG) activity of muscles latissimus dorsi (LD), biceps brachii (BC), pectoralis major (PM) and triceps lateral head (TC) were registered. The collection of EMG signals was performed according to the International Society of Electrophysiology and Kinesiology [9]. The analyses were made with the mean of the EMG signals calculated from the repetitions performed, excluding the first and the last repetitions. Raw EMG signals were recorded with a common mode rejection ratio of 100dB. The EMG signal was preamplified with a gain of 1,000 and bandpass-filtered (10-450Hz). The signal was sample data rate of 1,000Hz and rectified. The average of the amplitude was calculated using the root mean square (RMS) method. Bipolar active surface electrodes (silver; recording diameter = 1mm; distance between electrode center = 1cm) were used. The signal captured by EMG was analyzed in Matlab 5.02c (MathworksTM, Natick, USA) routines. The normalization of EMG signal was conducted through maximal voluntary isometric activation (MVIA). Three MVIA were performed against fixed resistance in function muscles positions [10]. The largest RMS value of the 3 MVIAs was used for normalization. The statistical analysis was initially done the Shapiro-Wilk normality test and by the homoscedasticity test (Barlett criterion). The paired T test was conducted to compare the number of repetitions performed in both protocols. EMG data were analyzed using a 1-way ANOVA with repeated measures to determine whether there were significant main effects or interactions, which was adjusted using the Bonferroni technique. An alpha level of $p \leq 0.05$ was used to determine the significance of comparisons.

RESULTS

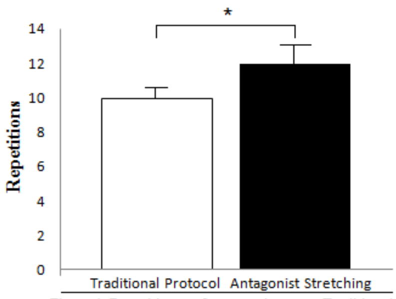

Figure 1. Repetition performance between Traditional Protocol and Antagonist Stretching during seated row exercise. *Significant differences between protocols for p < 0,05.

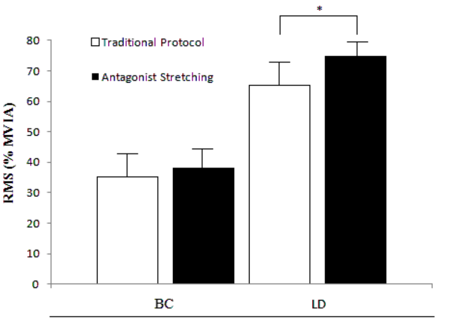

Figure 2. Comparison between Traditional Protocol and Antagonist Stretching during seated row exercise. RMS values for BC (Biceps Braquii) and LD (Latissimus Dorsi) muscles were normalized by MVIA. * Significant differences between protocols for p < 0,05.

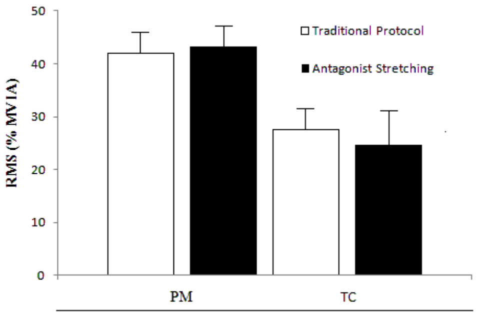

Figure 3. Comparison between Traditional Protocol and Antagonist Stretching during seated row exercise. RMS values for PM (Pectoralis Major) and TC (Triceps Lateral Head) muscles were normalized by MVIA.

DISCUSSION

In the present study, we observed a significant increase (p=0.01) in the number of repetitions of SR after AS compared to TP (Figure 1), in other words, the AS promoted improvement in agonists performance. The gains on performance of maximum repetitions in SR after AS may be associated with a significant increase (p=0.02) in EMG activity of LD (Figure 2), that likely plays the major role in SR exercise [11]. These findings may be associated with reduced of stiffness and increased length of rest sarcomeres during stretching of the shoulder adductors, whereas the morphological changes of SS it has been suggest the reduction in the activation of stretched muscle and relaxation of antagonistic muscles (shoulder abductors), thus, changing the length-tension relationship [2,3]. No differences were observed in the EMG signal of BC between TP and AS (Figure 2). These results could be justified by SS protocol adopted in the present study, which is specific for the shoulder adductors [4]. However, no significant differences were observed in the EMG signal of antagonist muscles PM and TC (Figure 3) after AS, so, the hypothesis of neural inhibition of the antagonists was not confirmed in the present study. Robbins et al. [7], reported that the reducing in the braking period of triphasic firing pattern (i.e, agonist-antagonist-agonist) are usually observed after fast or ballistic movements. Possibly the duration of the SS may not have been appropriated to promote changes in EMG activity of the antagonists, whereas the volume of stretching is directly associated with morphological and neural adaptations [1, 2, 3, 4]. Thus, there is not enough evidence to support the hypothesis of reduction in the coactivation of antagonist after SS, considering that many studies did not incorporating mechanistic approaches (e.g., EMG) to examine neural activity. Although, the bipolar electrodes do not reflect the EMG activity of the whole muscle, therefore, it is necessary to be careful about the interpretation and association of the amplitude of the EMG signal towards the activation signal sent from the central nervous system [9].

CONCLUSION

Therefore, these findings suggest an interesting alternative to enhance the repetition performance of agonist during exercises for upper-body muscles, whereas the steady enhance in muscle performance is associated with additional strength gains and improvement in functional capacity. Thus, others mechanisms should be investigated in future studies as the effects of AS in different muscle groups and movement patterns, as well as the interference of the AS volume on EMG signal of agonist and antagonist muscles.

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THE EFFECT OF LOW-INTENSITY RESISTANCE TRAINING WITH BLOOD-FLOW RESTRICTION ON SKELETAL MUSCLE RAPID FORCE CAPACITY

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INTRODUCTION

During the last decades low-load (20-50% 1RM) repetitive muscle contractions performed during blood-flow restriction has gained considerable interest, as it appears to increase human maximal muscle strength and skeletal muscle mass (Takarada *et al*., 2002) to a similar or greater extent as seen with heavy-load resistance training (Aagaard *et al*., 2001). The unique combination of low-intensity loading and efficient stimulation of muscle growth have prompted this training method to be recommended in rehabilitation settings where heavy-load training is contraindicated (e.g. in the initial phase after orthopedic surgery). Yet, perhaps the most important aspect of muscle contractile properties in regards to functional performance, the ability to produce force rapidly (e.g. rate of force development and/or muscle power) has not been investigated after a period of low-intensity resistance training with partial blood-flow restriction.

Thus, the aim of the study was to examine the effect of low-intensity resistance training with partial blood-flow restriction (BFR-training) on skeletal muscle rapid force capacity.

METHODS

10 young men (23 ± 2 yrs) completed 23.9 ± 0.3 sessions of low-intensity (20 % 1-RM load) blood-flow restricted knee extensor resistance exercise in 19 days. Training consisted of 4-sets of isolated knee extensor contractions (20% 1-RM loads) to concentric failure during concurrent blood flow restriction (100 mmHg cuff pressure). Muscle contractile properties were examined before (pre) and after (post) the training intervention. Unilateral maximal voluntary isometric muscle strength was measured for the knee extensors (m. quadriceps femoris) in an isokinetic dynamometer. The trial with the highest isometric peak torque (reported elsewhere, Nielsen et al. 2012) was used for the analysis of rapid force capacity; rate of force development (RFD; Δforce/Δtime) and contractile impulse (impulse = $\int$ torque dt) in the initial (0-30 and 0-50 ms) and late (0-100 and 0-200 ms) phase of rising muscle force, relative to onset of contraction. Furthermore relative RFD (rRFD) was obtained at 1/6, 1/2 and 2/3 of peak force (Aagaard et al. 2002).

RESULTS

RFD increased from pre to post with 16 % in the 0-30 and 0-50 ms intervals ($P<0.05$; $P<0.001$), respectively, while increases of 15 and 21 % were seen in the 0-100 and 0-200 ms intervals, respectively ($P<0.001$; $P<0.01$). Likewise, contractile impulse increased with 19, 17, 14 % in the 0-30, 0-50 and 0-100 ms intervals, respectively ($P<0.05$), while a tendency to an increase ($P=0.61$) was observed in the 0-200 ms interval. No changes emerged in rRFD from pre to post.

DISCUSSION

We here report an increase in RFD and contractile impulse in both the initial (0-30 ms and 0-50 ms) and late (0-100 and 0-200 ms) phase of contraction after 19 days of low-intensity BFR-training. Several previous papers have reported an increase in maximal voluntary isometric muscle strength after a period of BFR-training (Takarada et al. 2002; Abe et al. 2006). However, isometric maximal voluntary isometric muscle strength is usually achieved ≥ 300 ms (Thorstensson et al. 1976), and consequently may possess limited carry-over to activities of daily living. In fact, many every day movements require a certain level of force within a limited time frame (50-200 ms), e.g. the gait cycle and counteracting balance perturbations. Moreover, RFD is strongly correlated to functional ability in young and old patients (Suetta et al. 2004; Maffiuletti et al. 2010; Moreau et al. 2011), while a difference in RFD appear to distinguish between elderly fallers and non-fallers (Pijnappels et al. 2008) as well. Hence, the reported increases in RFD and contractile impulse in both the initial (0-30 and 0-50 ms) and late phase (0-100 and 0-200) of contraction would likely possess great functional carry-over in individuals suffering from muscle weakness. Thus, these data underline the potential of BFR-training in rehabilitation of individuals suffering from muscle weakness.

CONCLUSION

Short-term low-resistance training with partial blood-flow restriction is able to induce gains in rapid force capacity (i.e. RFD and contractile impulse), which further underline the potential of this training method in rehabilitation settings.

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COMPARISON OF SUPPORT AND KICKING LEG TIBIAL BONE STRENGTH STRAIN INDICES IN PROFESSIONAL FOOTBALL PLAYERS

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INTRODUCTION

In sport, the assessment of physical characteristics allows coaches and strength and conditioning professionals to determine both athlete potential and readiness to play. The assessment of muscular imbalance has been previously identified in athletes that must repeatedly perform single leg or single arm actions[1]. Although such an imbalance is often thought of as a negative characteristic, these specific adaptations are often due to years of sport specific stress that cause differential adaptation to the limbs due to different loads being chronically placed on the system. In Australian Rules Football (ARF), as for other kicking sports such as Soccer and Rugby, players will have a preferred kicking leg and support leg that will be exposed to different types of repetitive loads. Understanding if the skeletal system also preferentially adapts could be of use when monitoring and determining volume loads for specific activities and training. While dual energy xray absorptiometry has traditionally been used to assess bone and body composition in athletes, peripheral quantitative computed tomography (pQCT) provides much higher resolution imaging of the extremities and can be used to estimate actual fracture strength. Further, it is suggested that the use of pQCT may be a better predictor of bone fracture risk[2] and that specific measures of the bone morphology instead of BMD or BMC may be better determinants of bone strength[3,4]. A very novel aspect of this study is the application of this technique in athlete research. Therefore, it was the purpose of this study to examine if there are significant differences present in bone strength of the support limb versus the kicking limb in elite ARF players.

METHODS

Forty-six (age: 22.9 ± 3.8 years; height: 188.3 ± 6.6 cm; body mass: 85.5 ± 8.3 kg) professional ARF players participated in this study. Thirty of these players (Group A) were listed in the main squad and 16 (Group B) were categorized as less experienced with shorter training history and striving to be elevated to the main squad. Data was collected as part of the athlete's employment as a professional and all procedures and data management conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki). pQCT (XCT3000, Stratec, Germany) was used to scan the tibia of both the support and kicking limb at distances of 14% and 38% from the distal end. Structural strength of the bone was then determined using the Strength Strain Index (SSI) which is a density weighted bone section modulus. A composite SSI measure was determined as the average of the two sites. Statistical difference between groups for kicking leg, support leg and difference between legs was evaluated using one-way ANOVA with alpha set at 0.017 after Bonferroni adjustment for multiple variable comparisons. Differences between kicking and support limbs within each group were evaluated using paired t-tests with alpha similarly adjusted. Further, the relationship between the SSI of the kicking and support leg was assessed using Pearson product moment correlation coefficient.

RESULTS

Table 1. Strength Strain Index [mean(s.d.)] of kicking and support leg tibias of Football Players

	Kicking	Support	%difference
Group A (n=30)	2683(316)	2831(404)	4.74(6.15) [a]
Group B (n=16)	2295(183)	2333(225)	1.31(5.84)
%difference	14.5[b]	17.6[b]	3.43 [c]

[a]indicates significant difference between kicking and support leg
[b]indicates significant difference between elite and sub-elite
[c]indicates non-significant (p=0.074) difference between elite and sub-elite

Bone measures are provided in Table 1. SSI of both the kicking and support legs was significantly higher ($p < 0.001$) for Group A compared to Group B. SSI of the support leg was significantly greater than the kicking leg for Group A ($p<0.001$) but not Group B ($p=0.256$). The percentage difference between the two legs was 3.6 times greater for Group A than Group B but this was not statistically significant ($p=0.074$). For Group A there was a significant correlation ($r=0.898$, $p<0.001$) between SSI of support and kicking legs as well as the relationship of support leg SSI and percentage difference between the two legs ($r=0.573$, $p=0.001$). The same pattern was apparent for Group B between legs ($r=0.820$, $p<0.001$) and support leg SSI and difference between legs ($r=0.608$, $p=0.13$). There was no relationship between kicking leg SSI and difference between legs for either group.

DISCUSSION

There appears be a long-term adaptation of the bone strength of both the support and kicking limbs as a result of repeated kicking during football training and competition as indicated by significantly higher SSI for the more experienced athletes with longer training and playing history. Further, the more experienced players exhibited a significant difference in SSI between the two legs which is most likely due to the support limb being exposed to large and repetitive eccentric loads during the plant phase of the kick. Interestingly the less experienced players had not yet developed such asymmetry. Bone strength of kicking and support limbs is strongly correlated suggesting genetic factors in combination with career training loads result in increased SSI of both limbs. However, the difference between limbs is only correlated with support leg SSI suggesting it is the volume of kicking and other unilateral activities preferentially loading the support leg that induces the asymmetry.

Similar to other research associated with sidedness and bone adaption in athletes[4], the current research demonstrates that beneficial adaptations can occur not only to the muscle[1] but also to the bone, potentially to assist with load absorption. Of interest in these findings, is the potential to enhance bone strength of any limb by repeated eccentric load exposure such as those incurred by the support limb during kicking. This has implications for strength and conditioning practice as some athletes may exhibit low bone strength and thus higher fracture risk. Activities such as kicking and exercises which place similar eccentric loads on the supporting limb may be of benefit though longitudinal rather than cross sectional research is required to confirm this. This study suggests that bone morphology should be assessed in these professional athletes as it could have implications for bone injury risk and training program design[3].

CONCLUSION

Experience, training and competition history contribute to significantly higher bone strength of the lower limbs of football players. The tendency for these athletes to kick more frequently with a given leg results in markedly higher bone strength in the support leg which we hypothesize is due to the high eccentric loads occurring during foot plant. Better athletes exhibit greater asymmetry in bone strength most likely a result of longer history of kicking in training and competition. pQCT analysis should be considered for professional football players and appropriate strength and conditioning interventions implemented should markedly low SSI be determined as this may place the athlete at greater risk of fracture.

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EMGs ANALYSIS OF UPPER LIMB MUSCLES DURING DYNAMICAL CONTRACTION AT DIFFERENT INSTABILITY CONDITIONS AND EXECUTIONS

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INTRODUCTION

Resistance training at different conditions of instability and execution are believed to be useful for injury prevention, rehabilitation and general health benefits. The bench press is probably the most popular upper-body resistance exercise among athletes and recreational trainers. Previous studies have examined bench press on stable and instable conditions as well as different position [1, 2]. An additional aspect of resistance training that must be considered is the type of muscle action used. It has been well established that there are different neuromuscular demands associated with the use of concentric or eccentric muscle actions. Therefore, it is appropriate that each individual muscle action is examined to determine whether the instability may influence one type of muscle movement more than another. Thus, the effects of unstable surfaces on muscle activation of prime movers in bench press are unclear.

The aim of the present work is to investigate the behaviour of the muscles involved in the upper limb extensive kinetic chain analysing their neuromuscular activation at different angles and level of stability across the full ROM.

METODHS

Eighteen resistance-trained subjects (age 25.6 ± 5.6 yrs; heigth 174.2 ± 5,1 cm; weight 76.4 ± 8.9 kg) were evaluated performing six different exercises. Tested exercises are: flat bench press (BP), dumbbell bench press (DBP), dumbbell incline bench press (DIBP), flat dumbbell fly (FDF), dumbbell bench press on swiss-ball (BPSB), and Smith Machine bench press (SMBP). Load intensity have been set at 8 RM performing six repetition.

The recording procedure of the signals in dynamic conditions was done using multi-channel EMG arrays according to the most recent studies [3] in conjunction with shoulder angle recorded by means of an electrogoniometer as a trigger. A preliminary work has been conducted to locate the correct position of the array to remove IZ artefact on the signal. Surface EMG signals will be recorded from five locations of glenohumeral and scapulothoracic musculature: sternal portion of the pectoralis major (PM), anterior deltoid (AD), long head of triceps brachialis (TB), upper trapezius (UT), and serratus anterior (SA) muscles. To characterize neuromuscular activation amplitude signal average rectified value (ARV) was considered as dependent variables for concentric and eccentric portion of the movement.

RESULTS

For PM the ARV values of concentric phase were statistically grater when comparing SMBP with BPSB, DIBP and FDF ($p<0.05$) (Fig. 1). Comparing BP with DIBP and FDF were found statistically significant differences ($p<0.05$). There was statistically significant difference in muscle activity comparing BP with FDF ($p<0.05$) during the eccentric phase.

Statistically significant differences were reported for the ARV values of muscle AD when comparing the exercise FDF with SMBP and BP ($p<0.05$) for both concentric and eccentric phase. Further was found statistical significant difference between BPSB and FDF ($p<0.05$) in concentric phase.

The activity of SA was significantly lower when comparing FDF with SMBP, BPSB, BP, and DIBP ($p<0.05$) during the concentric phase. In the eccentric phase SA was lower comparing FDF with BP and SMBP ($p < 0.05$). TB reported greater electric activation amplitude ($p<0.05$) comparing SMBP with BPSB, DIBP, FDF and DBP during concentric contraction, whereas SMBP was grater comparing with DIBP and FDF in eccentric phase. Also BP was statistically significant different when compared with DIBP and FDF ($p<0.05$) in this phase. Activity of UT was increased performing DIBP comparing with FDF and DBP ($p<0.05$) during concentric phase and with BPSB, BP, FDF and DBP ($p<0.05$) during eccentric phase.

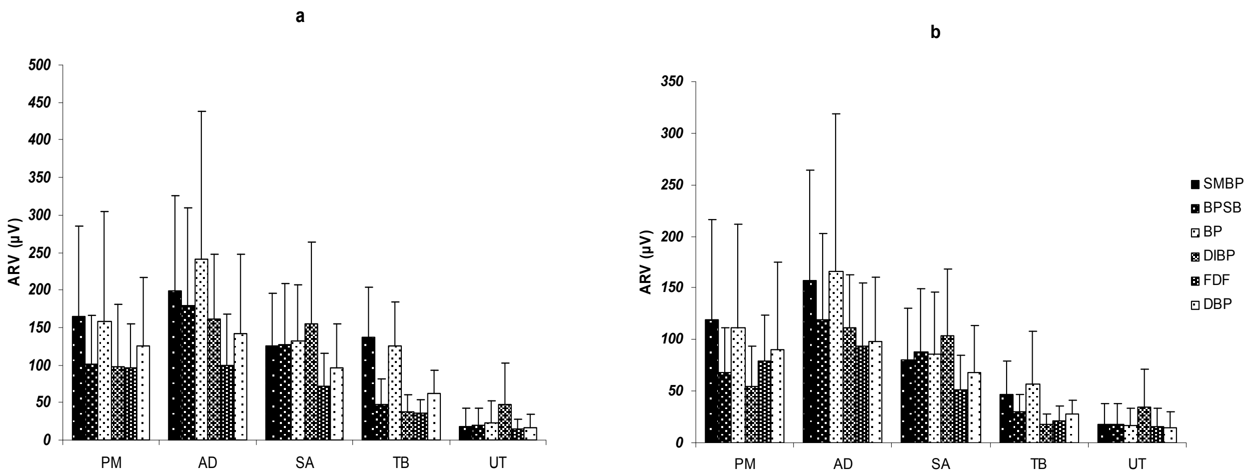

Figure 1. Mean ± SD of EMG average rectified amplitude of each muscle for each exercise tested during concentric phase (a) and eccentric phase (b).

DISCUSSION

Generally, activity of upper limb muscles seems to be increased when performing closed kinetic chain exercises as SMBP and BP. In particular PM, AD and TB muscles reported the greatest differences between exercises in both phases. These results show a superior effect of more constrained exercises on muscle activation of prime movers in bench press. Level of stability seems to establish a decreasing trend in electric muscle activation in particular for PM and TB. These results are consistent with the data of earlier investigations [1]. The mechanism for decreased activation of prime movers in the unstable conditions we employed could theoretically be increased stress associated with the postural demands. The body is a linked mechanical system and it is necessary to provide a strong base of support before heavy weightlifting. FDF reported lower electric activation between exercises showing that monoarticular open chain exercise does not obtain the same effects of other exercises in all muscles tested during concentric and eccentric contraction. Probably biomechanical load and level of coordination in this type of exercise are insufficient to stimulate a high level of muscle activity respect to closed kinetic chain exercises.

The activity of the main stabilizer muscles of the scapulothoracic joint (SA and UT) seems to be conditioned by angular position rather than level of instability. Indeed statistically significant difference were seen for UT comparing DIBP with FDF and DBP activation and for SA comparing DIBP with SMBP, BPSB, BP and FDF. These results are in agreement with previously reported study [4]. That is, because the more flexed shoulder position, the upper limb weight force vector tend to be less perpendicular respect trunk when performing exercises in horizontal position. This may result in increases in scapulothoracic muscle activity to contrast downward shoulder instability.

CONCLUSION

Knowing muscular behaviour during dynamic contraction is very important for coaches and therapists to improve athlete performance and rehabilitation exercise protocol. This study offers the possibility to identify precisely to movement technicians, the exercise or movement for their rehabilitation or performance training. Moreover, the results confirm the most recent publications that bind the muscular activation in inverse proportion to instability condition. Furthermore different coordination patterns may result in different muscle recruitment.

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SUPPORT FOR AN INDIVIDUALIZED APPROACH TO TRAINING IN AN UNDERPERFORMING PROFESSIONAL YOUTH SOCCER PLAYER

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INTRODUCTION: Adaptations to exercise are optimized when the training stimulus is focused towards an individual's needs and capacities; a training principle known as individualization (McArdle et al. 2007). However, owing to the number of players in a squad, individualized approaches can be impractical in the context of team sports such as soccer. In conditioning sessions that adopt a team-based approach, considerable inter-player variation can exist in the intensity of the training stimulus provided in a single session. Therefore, alternative strategies may need to be employed in those players identified as being less responsive to team-based conditioning sessions.

METHODS: Data is presented for an underperforming professional youth soccer player (Age: 16 years; Height: 1.73 m; Mass: 71.1 kg) whose maximal aerobic capacity had remained similar to pre-preseason values (54.7 $ml \cdot kg^{-1} \cdot min^{-1}$) despite participation in an 8 week preseason training program whereby a 4 ± 2% improvement in maximal aerobic capacity of the remaining members of the squad was observed (pre-preseason, post preseason: 57.7 ± 3.3 $ml \cdot kg^{-1} \cdot min^{-1}$, 59.9 ± 3.0 $ml \cdot kg^{-1} \cdot min^{-1}$, $P<0.001$). Moreover, empirical observations by the team's coaching staff identified that the player was underperforming in pre-season matches. Consequently, after three habituation sessions of treadmill running (5 sets of 4 min at 1% incline at 84-86% HR maximum; 2:1 work:passive rest ratio) and in addition to normal training, an interval training program consisting of 5 sessions of pitch (90 x 62-m) perimeter running (11-15 repetitions at 90-92% HR maximum; 1:1.5 work:passive rest ratio) was performed on one occasion per week in the first quarter of the competitive season. Each repetition was of a similar duration (i.e., within 5-s) and dependent variables measured throughout exercise were heart rate (HR: Polar S610 HR monitor, Polar, Finland) and distance covered.

RESULTS: In the final week of training, a 9% improvement in HR recovery was observed after the first repetition of pitch perimeter running when compared to the first training session (120 $beats \cdot min^{-1}$ vs. 133 $beats \cdot min^{-1}$) and enhanced HR recovery was observed in all repetitions thereafter (Figure 1). Similarly, exercise capacity in the final training session increased by 36% when compared to the first week (4560-m vs. 3344-m). Empirical observations by coaches supported an improvement in match performance post-training.

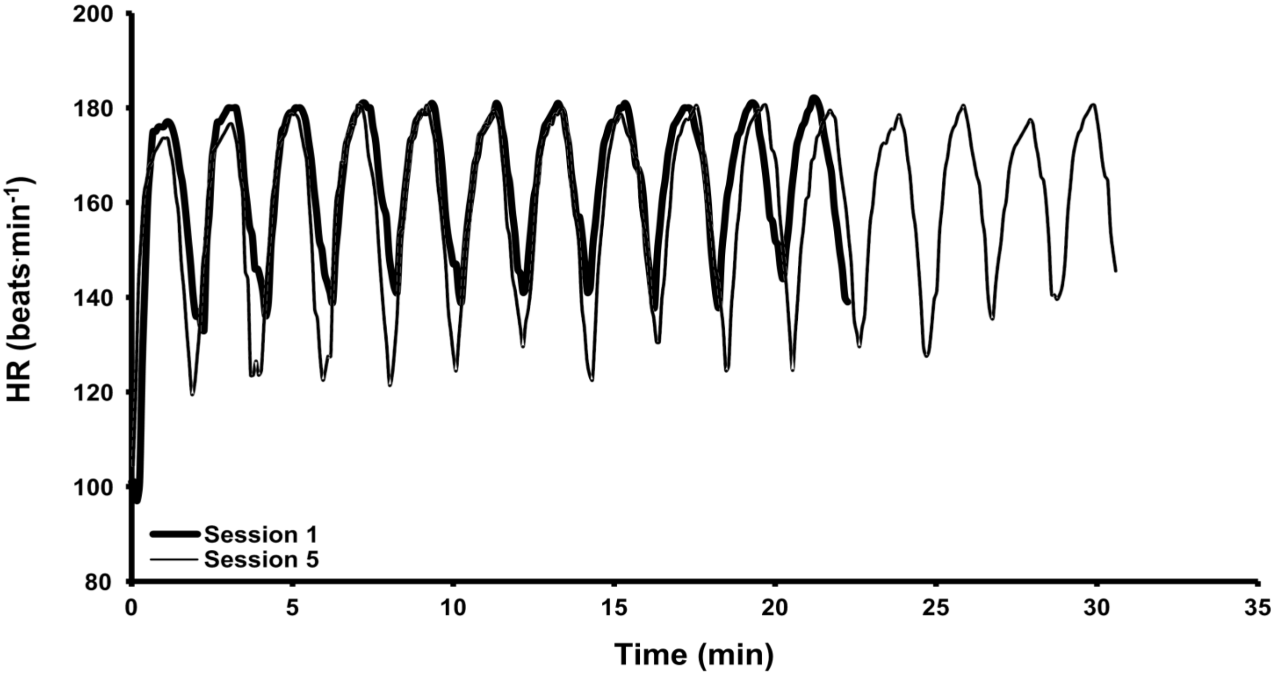

Figure 1: Heart rate response during the first and final session of interval training

DISCUSSION: These findings demonstrate that a 5-week individualized training program that required a single additional session per week to be completed was effective at promoting recovery between repeated sprint bouts and enhancing exercise capacity in an underperforming professional youth soccer player. Such data supports previous findings (Mujika et al. 2007) and is likely to have important implications for informing the training of soccer players; particularly those who are less responsive to team-based conditioning sessions.

CONCLUSION: An individualized approach to training is effective when seeking to positively influence adaptations in professional youth soccer players.

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FATIGUE INDUCED BY CROSS-COUNTRY SKIING INCREASES THE METABOLIC COSTS OF SUBMAXIMAL SKIING, BUT DOES NOT ALTER LEG AND UPPER-BODY EXPLOSIVENESS IN ELITE SKIERS

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INTRODUCTION

In elite cross-country skiers, performance, heart rate, oxygen uptake and peak blood lactate concentration has been shown to remain stable over three following 1100 m time trials with 1 hour recovery in between (Stöggl et al., 2007b). Another sprint skiing showed that the mean heat speed remained the same over three heats; however, the final sprint speed ("spurt") was significantly decreased over the heats (Zory et al., 2009 and 2011). Maximal strength and power have been correlated to peak skiing speed in cross country skiing (Stöggl et al., 2007a) and decrements in strength and power have been associated with fatigue after maximal exercise (Zory et al., 2009). Altogether, it might be suggested that elite skiers' explosiveness is more affected by fatigue than the physiological responses. In order to examine how explosiveness in the upper and lower limbs and the physiological responses are affected by fatigue more in detail, the current investigated upper and lower body peak power and submaximal roller skiing economy before and after incremental roller ski skating exercise to exhaustion.

METHODS

17 male cross country skiers (age 23.4 ± 3.8 years, body mass 73.7 ± 6.8 kg, body height 180 ± 5.5 cm and maximal oxygen uptake 70.7 ± 4.3 mL/min/kg) participated in the study. Initially, all skiers were tested for 1) maximal jump height in squat jump on a Kiestler force plate (Kistler Instrument Corp., Winterthur, Switzerland), 2) maximal power in a concentric bench press with a load of 50% of body mass and the average lifting speed measured by a linear encoder (MuscleLab, Ergotest Technology a/s, Langesund, Norway), and 3) physiological responses and rating of perceived exertion (RPE) during 5-minute submaximal roller-ski skating at 14 km/h with a 5% incline on a treadmill (Bonte Technology, Zwolle, the Netherlands). Thereafter, an incremental roller-ski skating test until total exhaustion with a 5% incline, a starting speed of 16 km/h and an incremental increase in speed of 1km/h every minute was executed. Squat jump and bench press was retested within 2 minutes after the incremental test and the 5-minute submaximal test was performed after 10 minutes including an active recovery.

RESULTS

During the incremental test to exhaustion, all skiers reached >98% of their maximal heart rate (193 ± 4.9 bpm), >19 in RPE (19.5 ± 0.4), and blood lactate concentrations of 12.7 ± 2.4 mMol/L. Maximal power in the squat jump and the bench did not change from the pretest to the posttest condition (Table 1). During the submaximal test, there was a significant higher heart rate, oxygen consumption, blood lactate concentration and RPE at the posttest condition compared to the initial test (Table 1; all $P < 0.05$).

Table 1: Maximal power in the upper and lower extremities, and physiological responses during 5-min submaximal roller ski skating pre and post to an incremental test to exhaustion when roller ski skating.

	Pre-test	**Post-test**
Maximal power:		
Power Bench Press (W)	349 ± 76	365 ± 74
Squat jump Height (cm)	33.2 ± 3.6	34.2 ± 4.2
Submaximal test:		
Heart Rate (bpm)	165 ± 13	171 ±12[#]
VO2 (ml/min/kg)	51.4 ± 2.8	53.4 ± 3.0[#]
RPE (6 to 20)	12.1 ± 1.9	14.2 ± 1.9[#]
Blood Lactate (mmol/l)	3.2 ± 2.0	7.1 ± 2.7[#]

= significant different from the pretest condition ($p < 0.01$).

DISCUSSION

The main findings of the present study were that that exhausting endurance exercise did not affect upper and lower body maximal power, but increased the submaximal metabolic costs of submaximal roller skiing (i.e, heart rate, oxygen consumption, blood lactate concentration and RPE-values). The maintained maximal powers are in contrast to earlier findings of Zory et al. (2009) showing decreased mvc in the knee extensors and upper body power following simulated sprint races in cross-country skiing. These differences between studies might in part be explained by higher performance levels of the present skiers, which have earlier been shown to have a better resistance to fatigue (Vesterinen et al., 2009) and a more rapid recovery (Sandbakk et al., 2011). The physiological profile of cross-country skiers, with high aerobic capacities, relatively low maximal strength and power capacities and with important requirements of maximal power abilities in the final “spurt” after long-lasting endurance exercise may possibly make them robust to reductions in maximal power. However, it remain to be examined whether the current results are affected by differences in muscle activity and fatigue between roller ski skating and the tested power exercises. The fact that all physiological responses when submaximal roller skiing was altered might indicate that a more technique specific fatigue was apparent. As skiing economy and efficiency has earlier been related to technique and technique specific power (Sandbakk et al., 2010), it can be speculated that neuromuscular fatigue affected these aspects.

CONCLUSION

The current study shows that fatigue due to incremental roller skiing exercise until exhaustion increased the metabolic cost of roller skiing, but did not decrease general upper and lower body maximal power in elite trained cross country skiers.

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ANKLE ISOKINETIC STRENGTH AND POSTURAL STABILITY IN "SLACKLINERS"

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INTRODUCTION

The slackline is a young physical activity with increasing popularity. Slacklining consists of walking or practicing balance exercises on a small, flat nylon rope (wide 2-5 cm) fixed between two points (usual length of 5-25 metres). The success of overcoming the slackline is given by a good level of postural stability (Granacher, Iten, Roth, & Gollhofer, 2010). These authors confirmed a positive influence of the slackline training on postural stability in a group of adolescents who have exercised for four weeks (3 times weekly) on unstable surfaces, including the slackline. It is postulated that balance training promotes a shift in movement control from cortical to subcortical and cerebellar structures (Taube, Gruber, & Gollhofer, 2008). The balance belongs to the abilities which are influenced by visual control, vestibular system and proprioception (Horvat, Nocera, Ray, & Croce, 2006). Several authors (Messier, Glasser, Ettinger Jr, Craven, & Miller, 2002) confirmed the relationship of a better stability with a greater strength in the ankle and knee joint.

The aim of the study was to assess isokinetic ankle strength of plantar and dorsal flexion and postural stability in slackliners.

METHODS

Nine slackliners (with the mean age of 25.0±0.9 years, body mass 74.6± 6.6 kg a body high 180.8± 6.4 cm) and nine physically active persons matched according the age (22.9± 0.8 years), body mass (73.3± 8.9 kg) and body height (181.0± 8.0 cm) took part in the study. The slackliners have at least two years' experience with the slacklining. No one from the control group reported any practice of balance exercises.

Concentric maximum ankle strength of flexion and extension was determined with an isokinetic dynamometer (Cybex NORM ®, Humac, CA, USA). The ankle flexion and extension were performed at the speed of $30°\cdot s^{-1}$ with 5 repetitions. Absolute and relative (Nm/kg body weight) peak torque (N·m) and time to peak (s) were evaluated. The postural stability was tested by 63s flamingo test on a pressure plate (FootScan®, Belgium). The trajectory of centre of pressure (COP) was used to assess the postural stability. The differences between groups ($p < 0.05$ and η^2) were evaluated by the analysis of variance. The statistics were computed with the statistical program SPSS for Windows Version 11.0 (Chicago, IL, USA).

RESULTS

The results of stability and isokinetic ankle strength are summarized in table 1.

Table 1: The results of postural stability and isokinetic ankle strength of plantar and dorsal flexion

		Slackline (n=9)		**Control group (n=9)**	
		Mean	**SD**	**Mean**	**SD**
Postural stability	COP TTW L (mm)	900	199	866.5	421
	COP TTW R (mm)	797.2	134	793.3	162
Isokinetic strength $30°\cdot s^{-1}$	**PF PTrel. L ($N\cdot m\cdot kg^{-1}$)***	**1.51**	**0.31**	**1.2**	**0.3**
	PF PTrel. R ($N\cdot m\cdot kg^{-1}$)†	**1.55**	**0.34**	**1.21**	**0.34**
	DF PTrel. L ($N\cdot m\cdot kg^{-1}$)	0.5	0.1	0.41	0.07
	DF PTrel. R ($N\cdot m\cdot kg^{-1}$)	0.47	0.07	0.45	0.1

	PF TP L (s)	0.46	0.08	0.48	0.08
	PF TP R (s)	0.49	0.06	0.48	0.11
	DF TP L (s)	0.48	0.13	0.53	0.22
	DF TP R (s)	0.48	0.16	0.53	0.16

*** $p<0.05$, $\eta^2=0.21$; † $p<0.05$, $\eta^2=0.22$.**

Variables: COP-Centre of pressure, TTW- Total trajectory way, L- left ankle, R- right ankle, PF- plantar flexion, DF-dorsal flexion, PT- peak torque, rel.-relative value, value/body weight, TP-Time to peak.

There were no significant differences between slackliners and control group in the total trajectory way of COP. The slackliners, on the other hand, have significantly higher plantar extension for angular velocity $30°\cdot s^{-1}$ in comparison with the control group. There were no other significant differences in strength characteristics.

DISCUSSION

Schweizer et al. (2005) reported that rock climbers showed significantly better results in the stabilometry (total trajectory way of COP) and greater relative maximum strength in the plantar flexion than soccer players (1.85 ± 0.2 vs. 1.52 ± 0.3 $N\cdot m\cdot kg^{-1}$, $p<0.05$). In the current study, we stated similar results only for ankle isokinetic strength but not for the postural stability. Similarities in results may be due to the slow controlled movement on a small support in climbing and in slacklining. Contrary, the discrepancy in postural stability is probably influenced by other factors as emotional state, testing conditions, etc.

Balance exercises, slacklining included, are recommended to improve the ankle instability (Messier, et al., 2002). The current study did not prove better postural stability in slackliners in contrast to other authors (Granacher, et al., 2010).

CONCLUSION

The results indicated that slacklining could enhance the plantar flexion strength associated with the ankle stability. The practice of slacklining may, therefore, be considered by kinesiotherapeutists in ankle rehabilitation programmes.

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POOR PREDICTION OF FIBER TYPE COMPOSITION WITH MULTIPLE PERFORMANCE TESTS AND SELECTED BIOLOGIC FACTORS: PRELIMINARY RESULTS

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INTRODUCTION

The fiber type composition of a muscle or a muscle group is of particular interest to researchers and athletes. Several studies have investigated the relationship between human performance and fiber type composition in certain muscles but the results were controversial. The purpose of the present study was to investigate the relationship between fiber type composition of vastus lateralis (VL) and various anaerobic performance tests as well as selected biological factors of the lower extremities, with multiple regression analysis in order to identify a predictive model for fiber type composition of VL.

METHODS

Thirty young untrained males (height 181±5, mass 77.2±5) performed twice and in random series the following tests: 60m sprint, ballistic leg press at 30%1RM, countermovement and squat jumps, 60sec jumping test (BT), underhand standing throws (6kg shot) and 30s Wingate test. Body composition was evaluated with dual x-ray absorptiometry. Dominant's leg thigh muscles cross sectional area (ThCSA) was estimated with anthropometry [1]. VL thickness, pennation angles and fiber lengths (ultrasonography) and fiber type composition (biopsy) were also evaluated. Statistical analysis included Pearson's correlation and stepwise regression. Another group of seven subjects with similar characteristics underwent all the above tests and their results were used to verify the predictive model found with the first group of subjects.

RESULTS

Preliminary analysis of our results revealed that percent area of VL covered with type II fibers was significantly correlated with peak power during the Wingate test (Pearson $r=0.52$, $p<0.01$). The best multiple regression predictive model for the type IIa fibers (%) in VL was expressed with the following equation ($r=0.915$):

*y=33.977-(84.567*BT flight time) + (0.204*ThCSA)*

However, when this formula was applied on the data from the second group of subjects, prediction of the type IIa fibers (%) in VL was poor (Table 1).

Table 1. Prediction of type IIa fibers (%) in VL using the multiple regression equation found in a larger group of subjects (see Methods).

Subjects	Type II fibers (%)	
	Biopsy analysis	Predictive model
1	38.7	35.1
2	40.5	26.8
3	48.6	37.2
4	36.0	43.2
5	32.0	45.0
6	30.7	48.3
7	48.1	43.8

DISCUSSION

A single muscle biopsy sample may not be representative of fiber type composition of the whole muscle or muscle group [2]. Moreover, human performance depends on multimuscular performance making it difficult to predict the fiber type composition of specific muscles. However further analysis of our results is needed.

CONCLUSION

Performance in anaerobic tests together with selected biological factors of the lower extremities cannot accurately predict the fiber type composition of vastus lateralis muscle.

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EFFECT OF ECCENTRIC EXERCISE-INDUCED MUSCLE DAMAGE ON HYPERTROPHY AND INFLAMMATORY GENES EXPRESSION

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INTRODUCTION

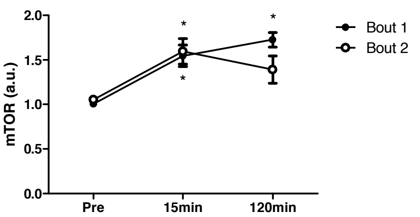
It has been suggested that exercise-induced muscle damage is a stimulus to hypertrophy [4, 8]. Morgan and Partridge [5] have shown that damage is associated with the release of growth factors (i.e. MGF) by the skeletal muscle. These growth factors may modulate signaling events in the Akt/mTOR pathway affecting positively protein synthesis [6, 9]. The activation of this pathway has been associated to the skeletal muscle hypertrophy after a period of mechanical stimuli [2, 3]. In addition, the inflammatory response caused by the damage may also contribute to the hypertrophy pathway activation and protein synthesis [7]. On the other hand, it is well known that the magnitude of eccentric exercise-induced muscle damage is attenuated in the successive exercise bouts [1]. Thus, it is plausible to assume that a repeated bout of eccentric exercise will cause less muscle damage, thereby inducing an attenuated inflammatory response, a smaller growth factors release and consequently smaller Akt/mTOR pathway activation. Thus, the aim of this study was to investigate the effects of two eccentric exercise bouts of the knee extensors on muscle damage indirect markers and mTOR, MGF, TNF-α, IL-1, IL-6, and IL-10 genes expression.

METHODS

Eight male subjects (33.9±10.8 yrs, 176.5±6.3 cm, 76.7±8.4 kg) participated in the study. They were submitted to two bouts of eccentric exercise (10x10 maximum repetitions, knee extension) 14 days apart. The knee joint was forcibly flexed from an initial position at 10° (from horizontal 0°) to a final 110° at $60°\bullet s^{-1}$. Indirect markers of exercise-induced muscle damage (maximum voluntary isometric contraction [MVIC], muscle soreness, and serum creatine kinase [CK] activity) were assessed pre- and 2, 24, 48, and 72 after each exercise bout. In addition, a muscle sample was obtained from the vastus lateralis of the subject's dominant leg through micro-biopsy technique pre-, 15, and 120 min after each exercise bout. MGF, mTOR, IL-1, IL-6, IL-10, and TNF-α genes expression were measured pre-, 15, and 120 min after each bout. Changes in muscle damage markers, hypertrophy and inflammatory genes expression were determined by two-way repeated measures ANOVA (exercise bouts x time intervals). Whenever a significant F-value was obtained, a Tukey *post-hoc* test was performed for multiple comparison purposes. Significance level was set at $p \leq 0.05$. Results are shown as means ± SEM.

RESULTS

Changes in MVIC, muscle soreness and CK activity after the eccentric exercise were not significantly different between bouts 1 and 2 ($p > 0.05$). Modifications in mTOR gene expression (Figure 1) were similar between exercise bouts. On the other hand, after the second bout, MGF gene expression (Figure 2) showed an early increase at 15 minutes (~2.4-fold induction, $p \leq 0.05$), reaching the highest value 120 min after exercise (~3.8-fold induction, $p \leq 0.05$). TNF-α and IL-6 also did not show significant difference between bouts 1 and 2 ($p > 0.05$) (Figures 3 and 4). However, IL-1 and IL-10 presented a significant increase at 120 minutes after both exercise bouts ($p \leq 0.05$) (Figures 5 and 6).



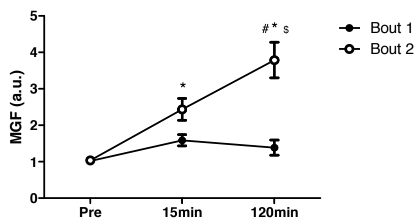
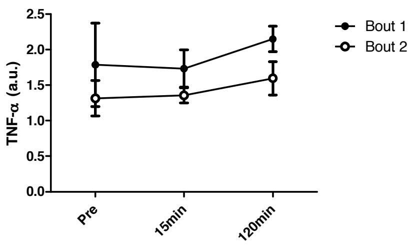


Figure 1- mTOR and **Figure 2-** MGF gene expression

* different from pre
\# different from 15min
$ different from bout 1



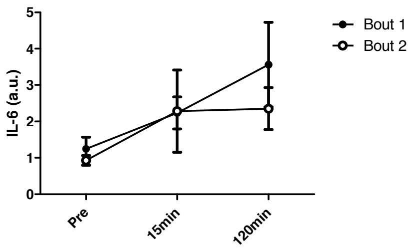
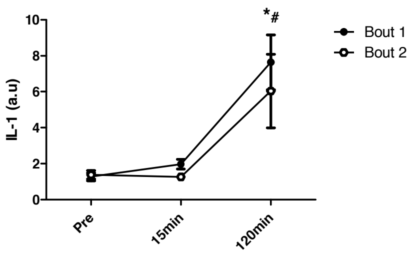


Figure 3- TNF-α

Figure 4- IL-6 gene expression



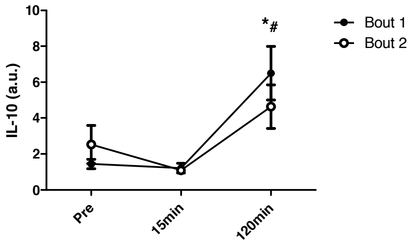


Figure 5- IL-1

Figure 6- IL-10 gene expression

*different from pre
#different from 15min

DISCUSSION

Exercise-induced muscle damage is usually evidenced by decreases in muscle strength, and increases in soreness and serum CK activity. It is well known that muscle damage magnitude is attenuated in the following exercise bout [1]. It should be mentioned that we observed a trend toward smaller changes (faster recovery) in MVIC and muscle soreness after the second bout. However, we did not find significant differences between exercise bouts in any muscle damage markers. Despite similar alterations in damage markers, there was a significant upregulation in MGF gene expression 120 min after the second exercise bout. Similar pattern was observed for IL-1 and IL-6 gene expression which presented a significant increase 120 min after the exercise bouts. Conversely, there were no significant changes in mTOR, IL-10, and TNF-α genes expression. Considering that acute damage/inflammation may play a positive role in skeletal muscle repair and growth, it was expected an increase in MGF and mTOR gene expression, after the first exercise bout and an attenuation in the response after the second bout since muscle damage could be reduced due to the protective adaptation (repeated bout effect).

CONCLUSION

We concluded that the magnitude of exercise-induced muscle damage seems to have a small effect on MGF but not on mTOR and inflammatory genes expression. It is possible that an optimal level of exercise-induced muscle damage is needed to positively affect hypertrophy pathway activation.

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MORPHOLOGICAL CHARACTERISTICS OF A TOP-LEVEL BODYBUILDER DURING PREPARATION FOR COMPETITION

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INTRODUCTION

For tracking of development and predicting of sport results in Kinesiology often is used trend analysis. Tracking of sports records dynamics gives insights to regularity which, by means of statistical methods, enables rational development predictions of sports results in the future. It also gives insights about perennial conditioning structure and technique training efficiency. A new training technology effects and quality of diagnostic devices applied are also benefits of the sports records tracking. In planning and programming of training processes, coaches, according to analysis results, get insights about results that have to be achieved for the upcoming competition. In trend analysis the most suitable events are those that can be accurately measured, like athletics, swimming, weight lifting, etc. Another very important issue is an expected result achievement rate, which gives general principles of individual result achievements that provides predicting of the most possibly results of an athlete (Wazny, 1978).

In previous studies, trend and results development rate were most often analysed, especially in athletics, such as high jump, held in Olympic Games in period 1948-1984 (Pavičić, 1987), shot put, held in Olympic Games in period 1896-1980 (Lukenda, 1988), or long jump and triple jump, held in Olympic Games in period 1948-1984 (Bogunović, 1990). Unfortunately, there is a lack of papers that inquiry subject's personal abilities and morphological characteristics, especially those of top-level athletes. Possible reasons are that diagnostic results of top-level athletes are confidential or that they are clinic and rehabilitation oriented.

In bodybuilding, morphological characteristics are of special interests, where one of the main purposes is to gain extra muscle mass and to lose as much as possible body fat. Development of muscle strength and muscle endurance and the gain of entire body muscle hypertrophy are secondary aims of bodybuilding (Quill, 2005). There are two basic periods in professional bodybuilding: *mass* and *definition* (Čorak, 2001). During the *mass period* the aim is to get extra muscle mass for the following competition. Fat mass is also expected, 15-17% (Too et al., 1998). Calories intake is increased and training sessions are based on high intensity resistance training. Aerobic activities are reduced or completely terminated. The main purpose of the *definition period* is to preserve as much as possible lean muscle mass gained in the *mass* period and also to reduce gained body fat (Čorak, 2001). In this period calories intakes are reduced (Rankin, 2002), resistance training volume is increased and intensity is decreased. Aerobic exercises are also present (Kelley and Kelley, 2006).

The main purpose of this study is to show how certain morphological characteristics have changed during *mass* and *definition periods*, and also to estimate a trend of morphological characteristics under programmed training process of a top-level bodybuilder.

METHODS

A measurement of the morphological characteristics was realized two times per month during preparation for bodybuilding contest *Mr. Univerzum 2006*, in period from 15, October 2005 till 7, October 2006, which resulted in a sequence of morphological variables. A body mass, a proportion of body fat, volume of the chest, volume of the waist, volume of the upper-arm during contraction in flexion, volume of the thigh during contraction in extension and volume of the shin were measured.

The series of regression analyses were performed to attain the relationship between training program and some morphological characteristics.

RESULTS

The results of regression analysis coefficients are presented in the table 1. Functions of the trends of some morphological characteristics of *mass* and *definition periods* are shown in the table 2.

Multiple correlations coefficients in the *mass period* are slightly lower than in *definition period*, with values 0.89-0.98 and 0.95-0.99, respectively. Correlation coefficients show that training process has a great influence on the morphological characteristics of the subject. Large coefficients of determination imply that there is a notable amount of concerted variance, i.e. about a great predictive power of a treatment influence on the morphological characteristics. Regression analysis gave the regression coefficients and time function of trends of morphological characteristics during *mass* and *definition periods* (Table 2). These regression coefficients represent mean dynamics values. Functions of *mass period* are best approximated as polynomial functions of third degree, and functions of *definition period* are best approximated as linear functions.

Table 1. Multiple regression coefficients (R), coefficients of determination (R^2) and p-level

		body mass	body fat	chest	waist	upper-arm	thigh	shin
mass	R	0.95	0.98	0.97	0.98	0.89	0.95	0.96
	R^2	0.90	0.96	0.95	0.96	0.79	0.90	0.93
	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00
definition	R	0.99	0.99	0.96	0.98	0.95	0.97	0.96
	R^2	0.98	0.98	0.92	0.96	0.90	0.95	0.93
	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. Functions of the trends of morphological characteristics in *mass* and *definition periods*

	MASS	DEFINITION
BODY MASS	$y = 117.5 + 4.3x – 0.3x^2 + 0.01x^3$	$y = 141.4 - 4.4x$
BODY FAT	$y = 7.9 + 2.2x – 0.2x^2 + 0.01x^3$	$y = 17.3 - 1.8x$
VOLUME OF THE CHEST	$y = 140.4 + 1.6x – 0.1x^2 + 0.03x^3$	$y = 149.0 - 1.5x$
VOLUME OF THE WAIST	$y = 90.6 +2.1x – 0.1x^2 + 0.001x^3$	$y = 103.1 - 3.5x$
VOLUME OF THE UPPER-ARM	$y = 51.6 + 0.4x – 0.02x^2 + 0.001x^3$	$y = 54.4 - 0.6x$
VOLUME OF THE THIGH	$y = 77.8 + 0.6x – 0.02x^2 + 0.003x^3$	$y = 82.1 - 0.6x$
VOLUME OF THE SHIN	$y = 50.5 + 0.1x + 0.01x^2 + 0.001x^3$	$y = 51.6 - 0.3x$

DISCUSSION

All morphological characteristic during *mass period* have steep trend of growth in first 10 weeks. For example, body mass increased for 20 kg, mostly because of 12 kg body fat. The remaining period of time is stagnation of morphological values. *Definition period* has a linear trend and affects equally during all period. Body mass decreases 2.19 kg per week, of which 0.88 kg belongs to body fat. It means that *definition period* primary affects body fat. Similarly, in the *definition period*, volumes of all measured characteristics decline under training processes. Specifically, the significant decline is noticed in variable volume of the waist where subject lost 1.72 cm per week. Consequently, there is also noticed a loss of lean muscle mass, but it is in line with the aim of the *definition period*.

CONCLUSIONS

Functions and trends of morphological characteristics of top-level bodybuilder were identified. They can be used as a model values in future preparations for competitions of this athlete and also other competitors with the same or similar morphological characteristics.

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ANAEROBIC PERFORMANCE AND ANABOLIC HORMONE PROFILE AFTER A HIGH FAT DIET FOLLOWED BY CARBOHYDRATE LOADING

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INTRODUCTION

The interaction between exercise training-induced responses and nutrient availability has long been recognized. The extent to which altering substrate supply can modify the training impulse has been a key research area among exercise scientists for several decades. Athletes have experimented with high fat diets for many years, with the objective of increasing fatty acid metabolism and sparing of muscle glycogen. Most of these studies were addressed to long distance aerobic endurance events. It has been well documented that long term, fat rich, low carbohydrate diets result in lower resting muscle and liver glycogen content and a higher rate of fat oxidation during exercise of low to moderate intensity (Helge 2002). On the other hand several studies have confirmed that low carbohydrate, high fat diets impair high intensity anaerobic performance (Helge 2002). There is little data available on the adaptive changes in substrate availability and exercise metabolism after a high fat diet followed by carbohydrate loading in relation to anaerobic performance.

METHODS

12 competitive, well trained basketball players were subjected to a 30s Wingate test under 3 different dietary conditions. Their average age, body mass and height was respectively 23±2,4 yrs. 195,2±3,7cm and 89,5±4,8kg. At first the players followed a mixed diet consisting of (50% CHO, 30% Fat, and 20% Pro) for 3 weeks. Secondly they consumed a high fat diet for 3 weeks (10% CHO, 70% Fat, and 20 % Pro), while the last part of the experiment included a 1 week carbohydrate loading phase, which included (70% CHO, 15% Fat, and 15 % Pro). The diets were isocaloric with an average daily energetic value of 3200±285kcal. At the end of each dietary procedure an all out 30s Wingate test (Excalibur Sport, Lode Netherlands) was performed preceded by a 15 min warm-up which included pedaling at 100W and stretching. Blood samples from the finger tip were drawn at rest and during the 4th min of recovery to evaluate pre and post exercise acid–base balance and lactate concentration. Additionally after each dietary procedure, at rest venous blood samples were taken to evaluate the concentration of glucose, insulin, GH, testosterone, and IGF-1. Body mass and body composition were also evaluated after each diet with the use of electrical impedance (In body 720 Biospace Co, Japan). After calculating the average values (x) and standard deviations (±SD), particular dietary procedures were compared by ANOVA.

RESULTS

The results of ANOVA indicate significant differences in total external work (F=5,32 p=0,001) and post exercise lactate concentration (F= 3,84 p=0,01) following the different diets. There were no significant changes in peak power reached on the average 3,79s after the start of the test (Fig 1). There were no significant differences in body mass and body composition although there was a tendency for a reduction in BM and Fat content following the high fat diet while an increase in these variables following the carbohydrate loading procedure (89,5kg vs. 88,1kg vs.90,2kg) and (9,4% vs. 8,9% vs. 9,7%). There were significant changes in blood glucose (F=6,25 p=0,001), insulin (F=0,8,96 p=0,001) and testosterone (F=3,47 p=0,01) concentrations following the mixed, high fat and high carbohydrate diets. There was a tendency towards increased concentrations of GH and IGF-1 after the high fat diet, yet these changes were insignificant.

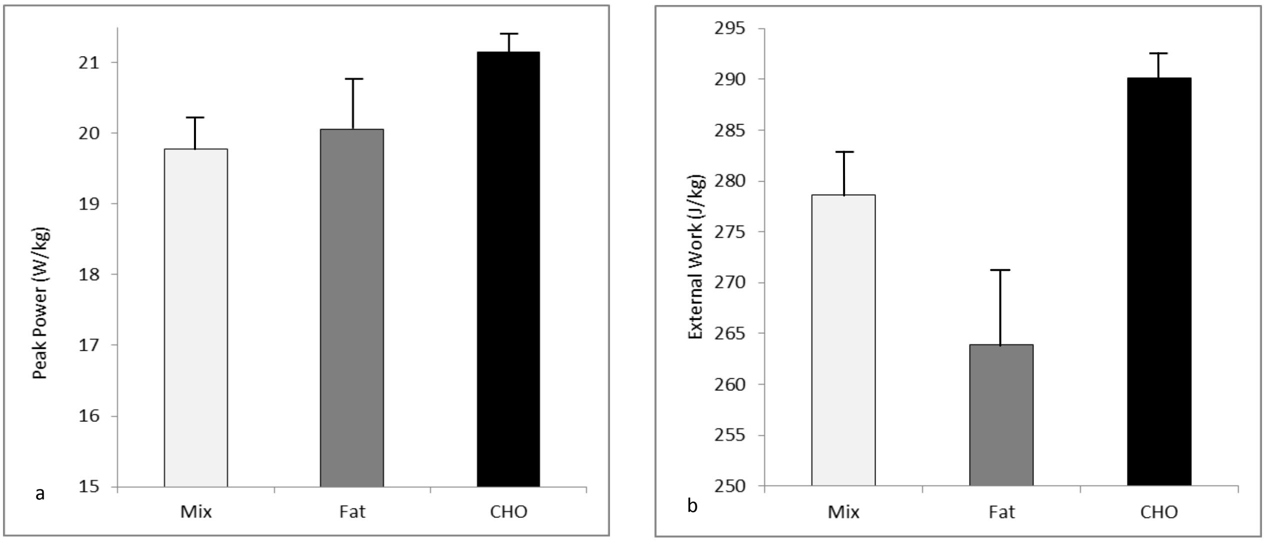

Fig 1.a,b. Changes in peak power (W/kg) and total external work (J/kg) following mixed (Mix), high fat (Fat) and carbohydrate loading diets (CHO)

DISCUSSION

A high fat diet does not affect peak power output, which is reache within the first 2-4 seconds of the exercise bout and most of the energy during this effort is derived from PCr. On the other hand anaerobic capacity evaluated by total work performed during the 30s exercise protocol is significantly decreased do to a high fat diet, which is most likely caused by lower muscle glycogen content and decreased activity of glycolytic enzymes at the cellular level (Jensen 2003). This phenomenon is confirmed not only by lower values of external work but also by decreased post exercise lactate concentrations. A high fat diet followed by a short phase of carbohydrate loading may allow for supercompensation of muscle glycogen stores, and significant increases in anaerobic capacity (Holoszy et al. 1998). This has been confirmed by significantly higher values of total work and post exercise lactate concentration (10,14 vs. 8,83 vs. 11,25 mmol/l) following the high carbohydrate diet. High fat diets allow for a decrease in body mass without compromising FFM and peak power, what may be caused by increased concentrations of free testosterone and GH and IGF-1, with a concomitant drop in insulin and glucose levels.

CONCLUSION

High fat, high protein diets can be used by athletes to reduce body mass and maintain peak power for performances lasting several second. Carbohydrate loading after a high fat diet may increase anaerobic capacity

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CHANGE OF METABOLIC CONSTITUENTS AND PERFORMANCE THROUGH A COMBINED SPORT INTERVENTION IN PATIENTS WITH IMPAIRED GLUCOSE TOLERANCE

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INTRODUCTION

The rapid increase of the incidence-rate of type 2 diabetes mellitus is a global problem. Physical exercise on a regular basis as part of a specific lifestyle intervention plays a central therapeutic role. The aim of this pilot study therefore was to explore, if patients with impaired glucose tolerance will benefit from an assisted sport intervention combining strength endurance and endurance training regarding their metabolic constituents and their performance.

METHODS

The study included seven female patients with impaired glucose tolerance. The female patients completed an assisted sport intervention in a therapeutical sports centre. The intervention included a device-supported strength endurance training (Milon Circuit) and an endurance workout on cardio machines. During their four-week adjustment period the patients twice a week. The work out consisted once of a ten-minute warm-up followed by a fifteen-minute strength endurance training and the other time of a ten-minute warm-up and a fifteen-minute stamina workout. Having completed their adjustment period the patients work out for the following nine weeks consisted of a ten-minute warm-up, a fifteen-minute strength stamina training as well as a fifteen minute stamina workout. The following data have been measured at the beginning (MPZ1) and immediately after the end of the sport intervention: the metabolism parameters (including OGTT); the performance parameter (bicycle spiroergometry, force measurement by means of Back-Check by Dr. Wolff); the anthropometric data and the body composition by means of bio impedance.

RESULTS

Due to impairment to health two patients could not take part in the second elevation (MPZ2). The average fasting glucose was at 5.79mmol/l or 5.76mmol/l. The 1 hour OGTT glucose level dropped from 11.5 mmol/l to 9.2mmol/l, the 2 hour OGTT glucose level from 6.3mmol/l to 5.3mmol/l. The HbA1c level rose from 5.58% to 5.78%. The average relative VO2max increased from 18.4ml/min/kg to 22.4ml/min/kg with an increase in performance VO2max from 99 to 111 watt at a heart rate of 141 or 140 bpm.

The average strength of trunk extension increased from 19.1kg auf 33.1 kg; the average strength of trunk flexion increased from 13.9kg to 25.8kg. The average body mass index decreased from 29.5kg/m² to 28.9kg/m². The fat cover and muscle mass were reduced from 31.7kg to 29.7kg and from 48.5kg to 48.3kg, respectively.

DISCUSSION

Through taking part in a combined three-months strength endurance and endurance sport intervention of female patients with impaired glucose tolerance could achieve improvements in their metabolic constituents as well as their performance parameters and body composition. The sport intervention conducted within this study therefore seems to represent a suitable training concept for female patients with impaired glucose tolerance. However, to ascertain the results of this pilot study further studies with a larger number of participants and a longer work interval should be conducted. These should also compare various training concepts.

CONCLUSIONS

A combined three-months strength endurance and endurance sport intervention of female patients with impaired glucose tolerance improved their metabolic constituents. However, to ascertain the results of this pilot study further studies with a larger number of participants and a longer intervention should be conducted.

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COMPLAINTS OF THE LOCOMOTOR SYSTEM OF DRAGON BOATERS COMPARED TO THOSE OF KAYAKERS

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INTRODUCTION

Since the 1990s dragon boating has become more and more popular. This is reflected in the rising number of organised members and in the sport becoming firmly established as a performance and competitive sport. The aim of the current study was to compare the complaints of the locomotor system of elite athletes in dragon boating to those of other water-sports. Most of these complaints are based on muscular disbalances (Knebel, 2011; Neumann, 2011).

METHODS

36 male and 29 female members of the national team of the German Dragon Boat Association have been questioned on subjective symptoms of the locomotor system within the past six months. The results have been compared to the data of a previous review on 21 male and nine female kayakers.

RESULTS

The complaints male dragon boaters described most frequently were concerning the back (33.3%). Further common complaints affected the shoulders (25%), the arms (19.4%) and the head area (16.7%). Female dragon boaters most frequently mentioned complaints in the head and shoulder area (41.4%), followed by back pain (31%). With male kayakers most complaints affected the back (71.4%), followed by shoulders (66.7%) and legs (47.6%). The complaints female kayakers most frequently mentioned concerned the back and shoulder area (55.6% each), followed by the arms (44%) und the head area (22%).

DISCUSSION

It was possible to establish a high incidence-rate of complaints of the locomotor system with dragon boaters. The main complaints are located in the areas of the back, the shoulders and the head. This differences concerning the area affected can be stated when compared with the main localisations mentioned by kayakers. This underlines the difference in strain on athletes in these two kinds of water sport. On top of that, there seem to be differences between male and female athletes in dragon boating as well as in kayaking. The reasons for this appear to be complex and should therefore be investigated in further studies. Therapeutical and prevention measurements are composition of muscular disbalances and stabilization of important muscles (Knebel, 2011; Neumann, 2011). There are research potential for a specific training for muscular balances. It should be under examination which method of strength training is useful.

CONCLUSION

In summary, there are a high incidence-rate of complaints of the locomotor system with dragon boaters. The main complaints are located in the areas of the back, the shoulders and the head. There seems to be differences to kayakers and between male and female athletes in dragon boating as well as in kayaking.

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EFFECTS OF 6 MONTHS STRENGTH TRAINING ON TYPE–2 DIABETES PATIENTS

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INTRODUCTION

The incidence of diabetes mellitus is a growing problem in the whole world. Worldwide, diabetes currently affects 285 million patients, what represents about 6,4 percent of population. Estimation for the year 2030 reaches as many as 435 million (IDF, 2009). Diabetes has been linked to the development of a variety of pathologies including heart diseases, stroke, peripheral vascular diseases and neurological disorders. The major benefits of resistance training in individuals with diabetes are increased muscle mass and resting metabolic rate, improved insulin sensitivity and blood glucose control.
The aim of the study was to evaluate, which kind of strength training provides most beneficial effects for type-2 diabetes patients in terms of positive changes of haemoglobin.

METHODS

The participants included 90 type-2 diabetes patients randomized into 3 groups.
Group 1 performed sets with 10-12 reps, group 2 with 25-30 reps and the third control group (group 3) did not do any exercise. The resistance training program consisted of 7 exercises activating larger muscle groups two times per week. The rate of perceived exertion after 4 weeks should have been „middle to a somewhat exhausting" (Buskies, 1999). The haemoglobin-A1c and drug application were recorded before and after intervention of about 6 month for all 3 groups. The parameter maximal power were recorded for the interventions group 1 and 2. The age range of subjects was between 48 and 77 years without significant difference among the 3 groups. The test persons included sedentary males and females who have not exercised for the previous 2 years.

RESULTS

The drop-out rate was 15.5 percent. The parameter maximal power improved in both group 1 und 2. In GR1 the strength of lumbar spine flexion increased from 235.6±113.7N to 373.5±218.7N (p=0.008). The strength of lumbar spine extension increased from 276.9±135.2N to 468.5±231.6N (p=0.000). In GR2 the strength of lumbar spine flexion increased from 271.3±105.8N to 414.6±211.3N (p=0.000). The strength of lumbar spine extension increased from 337.3±205.2N to 511.5±259.8N (p=0.000) (Fig. 1). Comparing the two groups no significant differences could be assessed in the change in value.
The haemoglobin reduced in group 1 from initial 6.73±0.57% to the final 6.44±0.69% (p=0.001). Group 2 reduced from 6.99±0.71% to 6.38±0.66% (p=0.000). The haemoglobin value of non-exercising control group increased non significantly by 0.10±0.37%. Additionally, in group 1 and 2 six persons were able to reduce dosage of their medication. On the other hand one patient from group 3 the dosage had to be increased (Fig. 2). The statistical analysis showed significant difference between groups 1 and 3 (p=0.001) and group 2 and 3 (p=0.001) respectively. There was no significant difference between group 1 and 2 (p = 0.288).

Group	test – maximal power	mean (N)	significance (p-wert)
GR1	flexion - lumbar spine	137.8±86.2	0.008
	extension - lumbar spine	191.6±112.2	0.000
GR2	flexion - lumbar spine	143.2±79.1	0.000
	extension - lumbar spine	174.2±123.7	0.000

Fig. 1 Effects of 6 months Strength Training on parameter change of maximal power in newton (N)

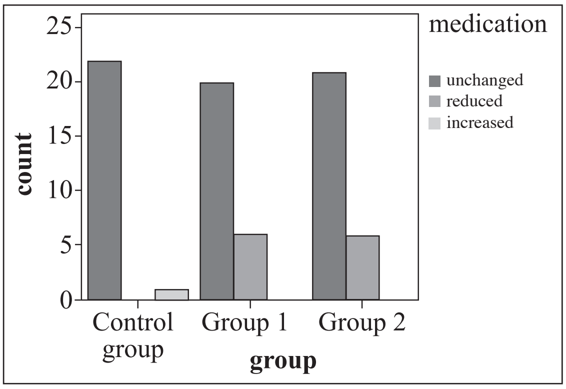

Fig. 2 Effects of 6 months Strength Training on parameter change of dosage of medication

DISCUSSION

The experimental group 1 and 2 have achieved during intervention period a significantly more reduction of haemoglobin-A1c than the control group. There was no significant difference between group 1 and 2. This distinctions intra-group with different contents of exercises is conform with the meta-analysis from Saam/Kann/Ivan (2006), even though the differences were not statistically significant. However, as building-up muscle mass and improving insulin sensitivity reflected by lower haemoglobin-A1c is a long term process, a longer intervention would be needed to achieve significant difference.

CONCLUSION

Both 6 month strength endurance training interventions (sets of 25 - 30 repetitions and 10 to 12 repetitions) are efficient sport therapeutic modality for patients with type-2 diabetes. There was no significant difference between group 1 and 2.

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