Reliability of the One-Repetition-Maximum Power Clean Test in Adolescent Athletes

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Abstract

Faigenbaum, AD, McFarland, JE, Herman, RE, Naclerio, F, Ratamess, NA, Kang, J, and Myer, GD. Reliability of the one repetition-maximum power clean test in adolescent athletes. *J Strength Cond Res* 26(2): 432–437, 2012—Although the power clean test is routinely used to assess strength and power performance in adult athletes, the reliability of this measure in younger populations has not been examined. Therefore, the purpose of this study was to determine the reliability of the 1-repetition maximum (1RM) power clean in adolescent athletes. Thirty-six male athletes (age 15.9 ± 1.1 years, body mass 79.1 ± 20.3 kg, height 175.1 ±7.4 cm) who had >1 year of training experience in weightlifting exercises performed a 1RM power clean on 2 nonconsecutive days in the afternoon following standardized procedures. All test procedures were supervised by a senior level weightlifting coach and consisted of a systematic progression in test load until the maximum resistance that could be lifted for 1 repetition using proper exercise technique was determined. Data were analyzed using an intraclass correlation coefficient (ICC[2,*k*]), Pearson correlation coefficient (*r*), repeated measures analysis of variance, Bland-Altman plot, and typical error analyses. Analysis of the data revealed that the test measures were highly reliable demonstrating a test-retest ICC of 0.98 (95% confidence interval = 0.96–0.99). Testing also demonstrated a strong relationship between 1RM measures in trials 1 and 2 ($r = 0.98$, $p < 0.0001$) with no significant difference in power clean performance between trials (70.6 ± 19.8 vs. 69.8 ± 19.8 kg). Bland-Altman plots confirmed no systematic shift in 1RM between trials 1 and 2. The typical error to be expected between 1RM power clean trials is 2.9 kg, and a change of at least 8.0 kg is indicated to determine a real change in lifting performance between tests in young lifters. No injuries occurred during the study period, and the testing protocol was well tolerated by all the subjects. These findings indicate that 1RM power clean testing has a high degree of reproducibility in trained male adolescent athletes when standardized testing procedures are followed and qualified instruction is present.

Key Words weightlifting, strength training, children, youth, fitness testing

Introduction

Resistance training has consistently demonstrated to be a safe and effective mode of exercise for children and adolescents provided that age-appropriate training guidelines are followed, and qualified instruction is available (10,25). Current public health objectives now aim to increase the number of school-age youth who participate in muscle strengthening activities, and the qualified acceptance of youth resistance training by medical and fitness organizations is becoming universal (3,9,23,29). However, methods for evaluating strength and power in younger populations remain controversial. Although 1-repetition maximum (1RM) testing is supported by the National Strength and Conditioning Association (NSCA) and has been used by researchers to assess muscular fitness in healthy children and adolescents (7,9,15,31), some observers remain opposed to maximal lifting in younger populations because of the presumption that high-intensity loading may cause structural damage (2). These differing views reported in the literature have resulted in ambiguity surrounding the issue of strength and power testing in youth. Moreover, little is known about the reliability of muscular fitness testing in young lifters.

In adult athletes, test criteria such as the 1RM power clean are routinely used to develop individualized programs and assess the effectiveness of a training cycle (16,20). The 1RM power clean assessment is unique because it can be used to test strength and power. Unlike traditional resistance exercises such as the bench press and back squat that are

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performed at a relatively low movement speed, the power clean is an explosive but highly controlled movement that is performed at a maximal movement speed. In the power clean exercise, a barbell is lifted from the platform to the shoulders in a single, continuous, forceful movement. Success with the power clean exercise involves complex and synchronized neural recruitment patterns and may provide a better impression of an athlete's whole body power relative to other resistance exercises. Accordingly, some experts hypothesize that power clean performance may be directly associated with sport-related power (7,19). In adult athletes, the power clean test provides a highly reliable measure of maximum muscular power (21,33). To our knowledge, no similar data exist that evaluate the reliability, validity, or safety of such testing with power clean movements in adolescent athletes. Given the link between power training and sports performance, it is paramount that pediatric researchers and youth coaches establish the reliability of power testing in youth.

The assessment of maximal muscular power is one of the most important determinants of athletic performance (7,11,19). Although field tests such as the standing long jump and vertical jump are typically used to assess anaerobic power in younger populations (6,22,28), weightlifting movements, such as the power clean, are perhaps the best measure of combined whole-body strength and power (14,19). During the performance of the power clean, the lifter must initially exert high forces to accelerate the barbell through the entire range of pulling without actively decelerating the barbell.

Although our laboratory has examined the safety, efficacy, and reliability of 1RM strength testing in children (12,13,22), an assessment of maximal power clean testing remains unexplored in younger populations. For the 1RM power clean to provide meaningful information to youth coaches and pediatric researchers, it is important to perform a reliability assessment of this measure in young lifters. Information pertaining to the reliability of 1RM testing in younger populations is vital for the accurate assessment of training outcomes and the replication of research experiments. This information is particularly important relative to the updated NSCA position statement article on youth resistance training that supports maximal lifting in younger populations provided age-appropriate guidelines are followed (9). Hence, the aim of this investigation was to assess the reliability of the 1RM power clean in a group of adolescent athletes.

Methods

Experimental Approach to the Problem

In this study, we assessed the reliability of the 1RM power clean in trained adolescents who had experience performing weightlifting exercises. Subject performed the 1RM power clean on 2 nonconsecutive test sessions (3–7 days apart) at the same time of the day (late afternoon). Test procedures were administered by a USA weightlifting senior level coach and consisted of a systematic progression in test load until the maximum resistance that could be lifted for 1 repetition using proper exercise technique was determined. This approach allowed us to carefully monitor the response of each subject to the testing protocol, individually evaluate 1RM performance, and assess the reliability of power clean testing in young lifters.

Subjects

The methods and procedures used in this study were approved by the Institutional Review Board for use of human subjects at the College, and informed consent was obtained from all parents and assent was obtained from each subject before participation. Thirty-six male athletes (age 15.9 ± 1.1 years, body mass 79.1 ± 20.3 kg, height 175.1 ± 7.4 cm) volunteered to participate in this study. All the subjects participated in interscholastic sports (primarily American football, basketball, and lacrosse) and were recruited from an after-school strength and conditioning program.

In this after-school program, the participants received daily instructions on weightlifting movements, resistance training, plyometric exercises, and speed and agility from Certified Strength and Conditioning Specialists and weightlifting coaches. As per the guidelines from USA Weightlifting (30), the participants learned how to perform the front squat; Romanian deadlift; and modified cleans, pulls, and presses with a wooden dowel before attempting to perform more advanced exercises. Progression was based on actual motor skill competence and technical proficiency. Proper exercise technique and lifting procedures that included instructions on how to safely "miss" a lift were reinforced during movement preparation activities and training sessions.

Training loads and exercises were progressed over time by members of the coaching staff as confidence and competence to perform advanced multijoint exercises improved. If an exercise was performed incorrectly, the lifters' performance was reassessed by a member of the coaching staff and, if appropriate, the training load was reduced. Only lifters who demonstrated proper exercise technique during training sessions participated in 1RM testing procedures to evaluate progress and determine appropriate training loads. On average, the subjects in this investigation had 16.5 ± 1.1 months of experience in performing various weightlifting movements, including the power clean and snatch exercises.

Both the subjects and their parents were informed about the objectives and scope of this project, and they completed a health history and physical activity questionnaire. The exclusionary criteria used were (a) subjects with a chronic pediatric disease and (b) subjects with an orthopedic limitation. All the volunteers were accepted for participation.

Procedures

A USA Weightlifting Senior Level coach who trained several young athletes at the National School-Age Weightlifting Championships evaluated performance on all 1RM lifts. Certified Strength and Conditioning Specialists who had

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experience testing and training school-age youth assisted with testing protocols. All study procedures took place after school (3:00–5:00 PM) during the Spring semester in a public high school strength and conditioning facility using competition-caliber Olympic barbells and plates. All the subjects were familiar with 1RM testing procedures and were evaluated individually by qualified professionals. Before testing, all the subjects participated in a 10-minute warm-up session, which included dynamic movement activities for the ankles, hips, shoulders, and wrists.

To perform the power clean exercise, the subjects placed their hands on the barbell slightly wider than shoulder width, with their hips lower than the shoulders and the barbell about 3 cm in front of the lower leg region (shank) with their feet about hip width apart. The subjects were reminded to "set the back" in the proper position with "chest up," elbows rotated outward, and eyes looking forward. The subjects initiated the power clean by deliberately lifting the barbell off the floor with a forceful extension of their knees and hips while keeping their shoulders directly over the barbell. During this phase of the lift, the arms and chest were "tight" and the barbell remained close to the body.

As the barbell rose above the knees, each subject explosively transitioned into the second pulling phase by extending their hips, knees, and ankles as if jumping into the air. When their lower body reached full extension, the subjects forcefully shrugged their shoulders with both elbows fully extended. The subjects avoided the temptation to bend their elbows during this phase of the lift, which is a common error in inexperienced lifters.

As the barbell continued to rise, the subjects quickly flexed their elbows, hips, knees, and ankles to pull their bodies under the barbell to catch the weight in a quarter-squat position with feet about shoulder width apart. By relaxing their grip during the catch phase of the lift, the subjects were able to receive the barbell across their shoulders with both elbows pointing forward. The subjects performed a quarter squat to the standing position once the barbell was located across the front of the clavicles and anterior deltoids. Although the power clean exercise consists of different phases, this movement requires the lifter to quickly and forcefully lift the barbell from the floor to the front of the shoulders in one continuous movement without interruption. Details of the power clean exercise have been previously described (14,26).

In our investigation, the 1RM was recorded as the maximum resistance that could be lifted using proper exercise technique for one repetition. Before attempting a 1RM, the subjects performed a progressive series of 5 submaximal sets of 1–2 reps with moderate to heavy loads (~50–90% of the estimated 1RM). Weights prescribed for warm-up sets and testing were based on a subject's previous weightlifting experience or prior 1RM test results, which were noted on a "testing helper" data sheet. If a weight was lifted with proper form during a 1RM trial, the subsequent 1RM weight attempt was increased by approximately 2.5–7 kg and the subject attempted another 1RM trial after approximately 3 minutes of rest. The increments in weight were dependent on the effort required for the lift and became progressively smaller as the subject approached the 1RM.

Appropriate progression of loading during 1RM trials was determined by a senior level weightlifting coach who trained all the subjects in this investigation. In the case of a failed 1RM lift, the subjects who attempted to maintain proper exercise technique without any major technical flaw in performance were permitted a second attempt at the same weight. Each subject's 1RM was determined within 3–5 trials. Qualified strength and conditioning professionals provided encouragement and reinforced the importance of proper exercise technique throughout all testing sessions with appropriate coaching cues. Three to seven days after the first 1RM trial, the subjects returned to the center in the afternoon and performed the second 1RM trial following the same testing protocol with the same instructors. The subjects were instructed to avoid heavy lifting for 48 hours before each testing session and observe proper nutrition practices, including adequate hydration. Throughout the study period, the subjects were questioned by test administrators for the occurrence of an injury or complaints of muscle soreness.

Statistical Analyses

Statistical procedures were performed using SPSS version 17.0 for windows (Chicago, IL, USA) and SAS version 9.1 (SAS Institute, Cary, NC, USA). Descriptive statistics were calculated for all variables. The relative reliability of the data was determined using a 2-way random effects model ICC(2,*k*), and Pearson correlation coefficient was calculated over the 2 test sessions. A repeated measures analysis of variance was used to evaluate any potential difference between test days, and the significance was set at $p \leq 0.05$. Bland-Altman plots, linear regression analysis, and typical error analyses (square root of mean square error) were also used to evaluate reliability. Accordingly, minimal differences (MDs) needed to be considered real were calculated (typical error $\times$ 1.96 $\times$ square root of 2) to provide a measure of the clinical significance of the observed changes in power clean performance. Data are reported as means and *SD*s.

Results

All the subjects completed the study according to the aforementioned methodology. The 1RM power clean was 70.6 ± 19.8 and 69.8 ± 19.8 kg on the first and second test session, respectively, with an intraclass correlation coefficient (ICC) of 0.98 (95% confidence interval = 0.96–0.99) and no significant difference in 1RM power clean performance between trials ($p > 0.05$). The Pearson correlation coefficient demonstrated a strong relationship between 1RM captured between test sessions ($r = 0.98$; $p < 0.0001$; Figure 1). The Bland-Altman plot is presented in Figure 2,

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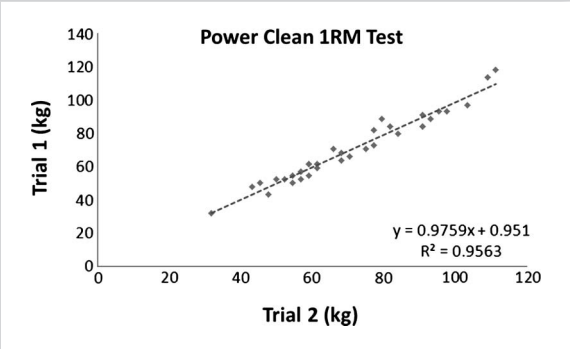

Figure 1. Scatterplot depicting the relationship between 1 repetition maximum (1RM) trials. The 95% confidence interval about the slope coefficient was 0.91–1.1.

and it confirmed no systematic shift between 1RM test sessions or association between difference and average with a calculated Pearson correlation of average vs. between method difference of $r = -0.10$ (=0.978). Linear regression (between the difference and the average) indicated an r-square of 0.00003, further confirming no association between difference and average measures. The degree of agreement between tests 1 and 2 was also evaluated by the mean difference and the 95% confidence limits. The average difference between the 2 testing trials was −0.751 kg, with a 95% confidence limit (−8.912 to 7.412), which indicates that the mean difference or error between test sessions was about 1% of the overall test measure in this population. The typical error to be expected with 1RM power clean between test measures is 2.9 kg. The MD = 8.0 kg indicates that changes >8.0 kg would be reflective of a real change in power performance with a retest or posttraining assessment. No injuries occurred throughout the study, and no complaints of muscle soreness were reported.

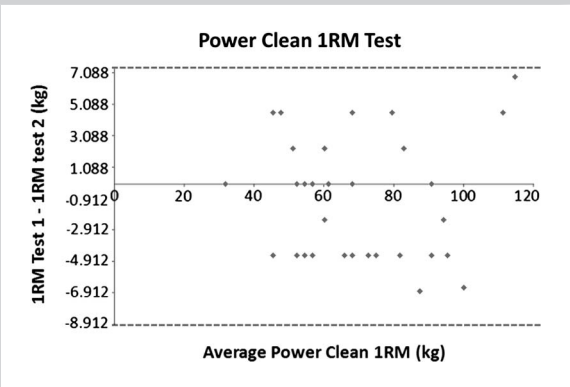

Figure 2. Bland-Altman plot of 1 repetition maximum (1RM) power clean performance. The solid line represents the mean difference between RM trials. The dotted line represents the 95% confidence limits for the measured difference.

Discussion

To our knowledge, no other study has examined the reliability of 1RM power clean testing in young lifters. The results of this investigation indicate that 1RM power clean testing has a high degree of reliability in trained male adolescent athletes when standardized testing procedures are followed and qualified instruction is given. No untoward responses or injury occurred from 1RM testing procedures. Despite previous concerns associated with 1RM power testing in youth (2), our findings support the updated NSCA article on youth resistance training and indicate that the maximal muscular power of healthy trained adolescences can be assessed with the 1RM power clean (9). However, it must be underscored that the subjects in this study were trained adolescent athletes who had experience in performing weightlifting exercises and that all procedures were administered by qualified professionals who were knowledgeable of pediatric resistance training guidelines and the pedagogical aspects of teaching weightlifting to school-age youth. The findings of this study may not be generalizable to untrained youth or to cases in which test protocols are administered by inexperienced professionals.

Although data on 1RM test-retest reliability in younger populations are limited, our data are consistent with those of previous reliability assessments performed on adult athletes. For example, McGuigan and Winchester reported an ICC of 0.98 for 1RM power clean testing in American football players (21). Because the ICC is a measure of relative reliability that examines the consistency of individual scores (32), the observed ICC of 0.99 in this investigation indicates that power clean testing is a highly reliable measure in trained adolescents. We have previously reported ICCs of 0.93–0.98 for the 1RM chest press and leg press tests in children (8–12 years) (12), and others have reported high ICCs on a variety of upper and lower body 1RM strength tests in adults (20). Of potential relevance, ICCs ≥ 0.90 have been found in children who performed sports-related tests of speed and agility and in adolescents who performed the drop vertical jump (1,31). Researchers have used the 1RM power clean to assess performance in adolescents, and a recent survey of high school coaches revealed that "Olympic style lifts" and its variations were the most important exercises these coaches prescribed for their athletes (6,8). Of note, data indicate that the risk of sustaining an injury during the performance of weightlifting movements during training or competition is relatively low provided that qualified instruction is available and safety measures are in place (5,10,15).

The Bland-Altman plots presented in Figure 2 show that the limits of agreement are small, suggesting that individual variability between 1RM trials was negligible in our subject population. The Bland-Altman plot also confirmed that there was no systematic shift (i.e., learned effect) between 1RM test sessions. The lack of association between difference and

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average also confirms that these methods do not provide systematic error. Moreover, linear regression (between the difference and the average) indicated an *r*-square of 0.00003, which represents cumulative and strong evidence that the 1RM test methods employed in the current population yield highly reliable outcome measures. From a practical perspective, highly reliable tests are able to detect small but significant changes in limited sample sizes and provide meaningful information to coaches and sport scientists regarding changes in physical performance (18). These findings indicate that the methods employed in this study would be appropriate to assess the effects of interventions on weightlifting performance in adolescent athletes.

In our investigation, the difference between 1RM testing trials was 0.8 kg (1.1%), and the subjects completed the 1RM tests with a mean of 3.1 and 3.4 trials, respectively, on days 1 and 2. In addition, the typical error to be expected between 1RM power clean trials was 2.9 kg, and it appears that a change of at least 8.0 kg is needed to identify real changes in power clean performance over time. The high reproducibility of 1RM power clean testing and acceptable measurement error in this study was likely because of a number of factors. Our population of adolescents had, on average, 16 months of experience in performing a variety of weightlifting movements in a structured strength and conditioning program. The subjects progressed from basic movements (e.g., front squat) to more complex movements (e.g., power clean) as competence and confidence improved. Although training frequency varied throughout the year depending on sport participation and school vacations, most of the subjects participated in strength and conditioning activities at least twice per week and received constructive feedback on proper form and technique from weightlifting coaches. As previously noted by Kraemer et al. (20), the process of increasing the weight to a true 1RM can be enhanced by prior familiarization with the testing exercise and the expertise of investigators who evaluate the performance of each lift. Of interest, Blazevich and Gill found significantly reduced reliability in an unfamiliar squat strength test in healthy adults who had at least 1 year of resistance training experience (4).

Despite the growing popularity of weightlifting by high school athletes and their coaches in the United States (8,27), only limited normative data are available on the power clean exercise for comparison. In the present investigation, the subjects lifted approximately 70 kg on the 1RM power clean, whereas the reported 50th percentile for this lift in 14- to 15-year-old high school American football players is 79 kg (17). Factors including training experience, testing procedures, quality of performance, and body mass may have influenced the observed differences in performance. Also, the subjects in our investigation participated in a variety of sports including American football, lacrosse, and basketball.

The results of this investigation indicate that 1RM testing of the power clean exercise can be used to track progress, develop personalized programs, and assess the effectiveness of youth strength and conditioning programs. In addition, 1RM testing can provide motivation during yearly training cycles. However, the proper administration of maximal strength and power testing procedures requires qualified instruction and consistent feedback on technical movements and desired intensity progression. Although these tests can be used by pediatric researchers and youth strength and conditioning professionals to assess training-induced gains in strength and power, field tests such as the standing long jump or vertical jump may be more appropriate in physical education classes as a general index of muscular fitness in youth.

This study attempted to determine the reliability of the 1RM power clean in trained adolescent athletes. Our substantive findings are consistent with those of similar tests measured in adults (21,33) and are supportive of previous investigations that examined 1RM strength testing in children (12,13). We found that technique-driven 1RM power clean testing has a high degree of reproducibility in trained adolescents and can be safely evaluated in young athletes provided that standard testing procedures are followed. However, no conclusions can be made regarding the reliability of power clean testing in inexperienced young lifters. Future research might focus on establishing normative 1RM power clean data for male and female high school athletes for comparative evaluations of maximal muscular power to age- and gender-matched peers.

Practical Applications

Muscular power is a key component to athletic ability in many sports, and there is growing interest in strength and conditioning in schools and youth sport training centers. The key finding from this study is that the 1RM power clean demonstrates excellent test-retest reliability and acceptable measurement error in trained adolescent male athletes. Because it is paramount for youth coaches to assess performance with tests that are reliable, the 1RM power clean can be added to protocols available to qualified professionals to monitor training-induced changes in strength and power and determine whether a real change in performance has occurred. It is also important for youth coaches to be able to reliably determine if gains in performance after a training program are real or an artifact of the measurement error associated with the test used to assess changes in performance. Our findings indicate that a difference in 1RM power clean performance of <2.9 kg between tests is an expected variation for this exercise. In addition, it appears that a change of at least 8.0 kg is needed to identify a real change in 1RM power clean performance as a result of strength and conditioning program in this young population.

Although administering 1RM power clean tests according to the procedures outlined in this study may yield reliable data, unsupervised testing procedures or poorly performed

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exercises are not recommended under any circumstances because of the potential for injury and reduced validity of test measures (24). Substantive and consistent instruction from qualified professionals is an integral component for achieving highly reliable test measures in young athletes who need to develop the coordination and skill technique to perform these lifts correctly. Because of the high degree of reproducibility demonstrated in this study, the 1RM power clean can be considered a useful and meaningful test in high school strength and conditioning programs provided criteria-based testing guidelines are followed and practitioners have experience measuring parameters of weightlifting performance in young lifters.

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References

1. Alricsson, M, Harms-Ringdahl, K, and Werner, S. Reliability of sports related functional tests with emphasis on speed and agility in young athletes. *Scand J Med Sci Sports* 11: 229–232, 2001.
2. American Academy of Pediatrics. Strength training by children and adolescent. *Pediatrics* 121: 835–840, 2008.
3. Behm, DG, Faigenbaum, AD, Falk, B, and Klentrou, P. Canadian society for exercise physiology position paper: Resistance training in children and adolescents. *Appl Physiol Nutr Metab* 33: 547–561, 2008.
4. Blazevich, A and Gill, N. Reliability of unfamiliar, multijoint, uni- and bilateral strength tests: Effects of load and laterality. *J Strength Cond Res* 20: 226–230, 2006.
5. Byrd, R, Pierce, K, Rielly, L, and Brady, J. Young weightlifters' performance across time. *Sports Biomech* 2: 133–140, 2003.
6. Channell, BT and Barfield, JP. Effect of Olympic and traditional resistance training on vertical jump improvement in high school boys. *J Strength Cond Res* 22: 1522–1527, 2008.
7. Cronin, J and Sleivert, G. Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Med* 35: 213–234, 2005.
8. Duehring, MD, Feldmann, CR, and Ebben, WP. Strength and conditioning practices of United States high school strength and conditioning coaches. *J Strength Cond Res* 23: 2188–2193, 2009.
9. Faigenbaum, A, Kraemer, W, Blimkie, C, Jeffreys, I, Micheli, L, Nitka, M, and Rowland, T. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *J Strength Cond Res* 23: S60–S79, 2009.
10. Faigenbaum, A and Myer, G. Resistance training among young athletes: Safety, efficacy and injury prevention effects. *Br J Sports Med* 44: 56–63, 2010.
11. Faigenbaum, A and Westcott, W. *Youth Strength Training*. Champaign, IL: Human Kinetics, 2009.
12. Faigenbaum, A, Westcott, W, Long, C, Loud, R, Delmonico, M, and Micheli, L. Relationship between repetitions and selected percentages of the one repetition maximum in healthy children. *Pediatr Phys Ther* 10: 110–113, 1998.
13. Faigenbaum, AD, Milliken, LA, and Westcott, WL. Maximal strength testing in healthy children. *J Strength Cond Res* 17: 162–166, 2003.
14. Garhammer, J. A review of power output studies of Olympic and powerlifting: Methodology, performance prediction, and evaluation tests. *J Strength Cond Res* 7: 76–89, 1993.
15. Hamill, B. Relative safety of weight lifting and weight training. *J Strength Cond Res* 8: 53–57, 1994.
16. Harman, E and Garhammer, J. Administration, scoring and interpretation of selected tests. In: *Essentials of Strength and Conditioning*. T. Baechle and R. Earle, eds. Champaign, IL: Human Kinetics, 2008. pp. 249–292.
17. Hoffman, J. *Norms for Fitness, Performance and Health*. Champaign, IL: Human Kinetics, 2006.
18. Hopkins, WG. Reliability of power in physical performance tests. *Sports Med* 31: 211–234, 2001.
19. Hori, N, Newton, H, Nosaka, K, and Stone, M. Weightlifting exercises enhance athletic performance that requires high-load speed strength. *Strength Cond J* 27: 50–55, 2005.
20. Kraemer, W, Ratamess, N, Fry, A, and French, D. Strength training: Development and evaluation of methodology. In: *Physiological Assessment of Human Fitness*. P. Maud and C. Foster, eds. Champaign, IL: Human Kinetics, 2006. pp. 119–150.
21. McGuigan, M and Winchester, JB. The relationship between isometric and dynamic strength in collegiate football players. *J Sports Sci Med* 7: 101–105, 2008.
22. Milliken, LA, Faigenbaum, A, Loud, R, and Westcott, W. Correlates of upper and lower body muscular strength in children. *J Strength Cond Res* 22: 1339–1346, 2008.
23. Mountjoy, M, Armstrong, N, Bizzini, L, Blimkie, C, Evans, J, Gerrard, D, Hangen, J, Knoll, K, Micheli, L, Sangenis, P, and Van Mechelen, W. IOC concensus statement: Training the elite young athlete. *Clin J Sports Med* 18: 122–123, 2008.
24. Myer, G, Quatman, C, Khoury, J, Wall, E, and Hewett, T. Youth vs. adult "weightlifting" injuries presented to United States Emergency rooms: Accidental vs. non-accidental injury mechanisms. *J Strength Cond Res* 23: 2054–2060, 2009.
25. Myer, G and Wall, E. Resistance training in the young athlete. *Oper Techn Sports Med* 14: 218–230, 2006.
26. Newton, H. *Explosive Lifting for Sports*. Champaign, IL: Human Kinetics, 2002.
27. Pierce, K, Bryd, R, and Stone, M. Youth weightlifting–Is it safe? *Weightlifting USA* 17: 5, 1999.
28. Safrit, M. *Complete Guide to Youth Fitness Testing*. Champaign, IL: Human Kinetics, 1995.
29. United States Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. Available at: www.health.gov/paguidelines, 2008. Accessed December 8, 2010.
30. USA Weightlifting. *USA Weightlifting Club Coach Manual*. Colorado Springs, CO: USA Weightlifting.
31. Walsh, M, Ford, K, Bangen, K, Myer, G, and Hewett, T. The validation of a portable force plate for measuring force-time data during jumping and landing tasks. *J Strength Cond Res* 20: 730–734, 2006.
32. Weir, J. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res* 19: 231–240, 2005.
33. Weiss, L, Moore, C, Schilling, B, Ermert, R, Fry, A, and Chiu, L. Reliability and precision of multiple expressions of hand power clean bar velocity. *J Strength Cond Res* 19: e36, 2005.

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