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Muscle performance and functional capacity retention in older women after high-speed power training cessation

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ABSTRACT

Power declines more steeply than strength with advancing age and training cessation among older women and is associated with the loss of functional ability. We tested the hypothesis that the impact of 6 weeks of detraining (DT) subsequent to 12 weeks of high-speed power training on maximal strength (1RM) of the arm and leg muscles, power performance (counter movement jump and ball throwing) and functional task (sit-to-stand test) would decrease physical performance, and specifically power performance.

Thirty-seven older women were divided into an experimental group and a control group [EG, n = 20, 65.8 (2.5) years; CG: n = 17, 64.8 (2.8) years]. Muscular strength, power and functional testings were conducted before the initiation of training (T1), after 12 weeks (T2) and after 6 weeks of DT (T3).

During the 12 weeks of training, EG significantly increased their dynamic strength performance (range from 41.9 to 64.1%), muscle power output (range from 18.2 to 33.6%) ($p<0.05$) and function (15.8%) ($p<0.05$). No significant differences were observed in the magnitude of the increases in CG. Short-term DT led to larger effects on maximal strength (18.1–23.8%) ($p<0.05$) of both upper and lower extremity muscles than in muscle power (2–4.5%) and function (2.8%) ($p<0.05$). However, all measurements remained higher (12.6–36.4%; $p<0.05$) than in pre-training levels.

These data indicated that DT may induce larger declines in muscle strength than in power output and preserved physical independence, mediated in part, by the effectiveness of high-speed power training particularly developed for older women.

1. Introduction

Aging has been related with muscular atrophy and decreased functional performance resulting in reduced ability to perform daily tasks (Aagaard et al., 2010; Carvalho et al., 2009). Furthermore, a slowed capacity to develop high velocity movements and lessened responsiveness to preventing falls in the lower and upper limbs are associated with disability and are a significant cause of injury (Häkkinen et al., 2000; Pereira et al., 2012). Even though older people have been found to be weaker and less powerful, a limited amount of research has focused on determining the influence of high velocity strength protocols on power and explosive arm and leg muscle tasks rather than on the effects of traditional resistance training regimens in older women (Häkkinen et al., 2000; Pereira et al., 2012). Determining this influence may promote greater understanding of the potential of muscle power training focused on high-speed power training to promote therapeutic developments in older populations (Bickel et al., 2011; Fieo et al., 2010; Reid and Fielding, 2012).

Older women often experience interruptions in training sessions (Ivey et al., 2000; Lemmer et al., 2000) because of illness, injury, or other factors, which may result in a reduction or cessation of their normal physical activity level (Carvalho et al., 2009; Henwood and Taaffe, 2008). The magnitude of this reduction may depend upon the length of the detraining (DT) period (Izquierdo et al., 2007; Toraman, 2005) together with training levels previously attained by the subject (Williams and Thompson, 2006). Little is known about the regressive effects of a detraining period in older women once the training intervention has ended (Henwood and Taaffe, 2008). Although, the residual effects of power or strength training seem to be appropriate after a period of interruption to promote physical independence (Häkkinen et al., 2000; Henwood and Taaffe, 2008).

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This investigation has importance given that we are finding that targeted interventions specific to age, gender and capacity have greater value than a one size fits all model (Reid and Fielding, 2012). The hypothesis argued in this paper is that older women can significantly increase the physical parameters of maximal dynamic strength and functional performance with high-speed power training over a consecutive 12-week period. Additionally, a 6-week DT period may produce significant decreases in physical performance, namely in power performance. Therefore, the aim of this study was to investigate the changes in physical parameters produced during a high-speed power training and DT in older Caucasian women.

2. Methods

2.1. Experimental design and approach to the problem

To investigate the effects of high-speed power training over a consecutive 12-week period and a 6-week DT period, older Caucasian women were divided into two groups. These were a control group that did not undergo any physical activity and an experimental group that carried out a resistance training focused on high velocity training over 12 weeks which had previously shown large effect gains in strength and power performance as well as functional capacity in upper and lower extremity muscle performances (Pereira et al., 2012).

Besides assessing physical performance after a 12-week period of high-speed power training, our goal was to evaluate the effects of a 6-week period of DT on maximal strength in bench press and leg extension, muscle power of both upper and lower extremity muscles and function capacity.

Thus the aim of the present study was to expand our previous results comparing the residual effects of muscle power and muscle strength training following extended detraining.

However, to test the stability and reliability of the performance variables, a given section of the sample was evaluated consistently at the same time and location and supervised by the same researchers at pre- and post-interventions. Subjects were evaluated twice before the start of training (weeks −2 and 0), and this served as a control period. In addition, the stability and reliability of these variables had been previously tested using a higher number of older women subjects over a control period (Pereira et al., 2012). Tests were applied to both groups at two intervals: before the experimental period (T1) and after the 12-week experimental period (T2). Immediately following this, subjects started a 6-week DT period (T3). The test–retest reliability for all considered strength and power measurements was performed; the intra-class correlation coefficient (ICC) was always higher than 0.90.

2.2. Subjects

Thirty-seven healthy older Caucasian women were divided into two groups (hereafter EG and CG): the experimental (n = 20; age: 64.8 ± 2.8 years; body mass: 65.5 ± 10.0 kg; height: 1.53 ± 0.06 m) and the control (n = 17; age: 65.8 ± 2.5 years, body mass: 65.2 ± 6.5 kg and height: 1.55 ± 0.04 m) (Table 1). Apart from daily routine tasks, the experimental group (EG) underwent a resistance training program of three training sessions per week over 12 weeks. None of the participants had a history of resistance training. Before inclusion in the study, all candidates were thoroughly screened by a physician. Written informed consent was obtained from each participant. The experimental procedures were approved by the University of Trás-os-Montes and Alto Douro, Department of Sport Sciences, according to the Helsinki Declaration.

A detailed description of the testing procedures has been given elsewhere (Pereira et al. 2012). In brief, total height (m) and body weight (kg) were assessed according to international standards for anthropometric assessment. To evaluate height a stadiometer (SECA, model 225, Germany) with a range scale of 0.10 cm was used and body mass (kg) was measured to the nearest 0.1 kg using a digital scale (Philips, type HF 351/00).

2.3. Maximal strength, power and functional tests

Lower- and upper-body maximal strengths were assessed using one-repetition concentric maximum (1RM) actions in a leg extension ($1RM_{LE}$) and in bench-press ($1RM_{BP}$) position, respectively. The power output of the leg muscles was measured concentrically in a vertical jump using a trigonometric carpet (Ergojump Digitime 1000; Digitest, Jyvaskyla, Finland) to assess maximum height in counter-movement jump (CMJ). For arm extensor power a ball throwing performance (BT) was tested with a 1.5 kg medicine ball (Ø 0.60 m). Functional performance was evaluated using the 30-second sit-to-stand test (STS).

2.4. High-speed power training protocol

The high-speed power training protocol consisted of three sessions per week over 12 consecutive weeks. The innovative training consisted of progressively increased loads by 40%–75% of 1RM; 3 sets: 4–12 reps and maximal muscle activation during explosive exercises such as countermovement jump and medicine ball throwing similar to those reported previously (Pereira et al. 2012). To reduce participant dropout, music was played during all sessions and adherence was assessed at every session. Postgraduate sports researchers ensured that exercises were correctly performed. Sessions were deemed complete when at least 90% of the prescribed exercises had been successfully performed.

Detraining took place over a period of six consecutive weeks coterminous with the summer holidays. All sample subjects undertook no formal physical activity or institutional training programs during DT period. During this period, EG participants were instructed to give details of any new prescribed medication and to continue only with their usual daily activities. The testing assessment procedures after the DT were collected at the same time and place and on the same day as for the usual training. Data collection was again performed by the same investigators.

Table 1
Changes in the anthropometric characteristics of the subject's during baseline, training and detraining.

Variable	Group	T1	T2	T3	P-value (T1 vs. T2)	P-value (T2 vs. T3)
		x ± σ	x ± σ	x ± σ		
Body weight (kg)	CG	65.2 ± 6.5	64.7 ± 6.2	64.8 ± 6.2	0.063	0.070
	EG	65.5 ± 10.0	65.8 ± 10.1	65.9 ± 10.1	0.393	0.408
BMI ($kg.m^{-2}$)	CG	27.0 ± 2.6	26.8 ± 2.5	26.9 ± 2.5	0.066	0.181
	EG	27.7 ± 3.7	27.8 ± 3.7	27.9 ± 3.8	0.375	0.335
Total standing height (cm)	CG	155 ± 0.04	155 ± 0.04	155 ± 0.04	0.292	0.543
	EG	154 ± 0.06	154 ± 0.06	154 ± 0.06	0.292	0.163

Data presented are mean ± *SD*; p-value (T1 vs. T2) — statistical differences within each group between pretraining and posttraining evaluations (T1 and T2); (T2 vs. T3) — statistical differences within each group between posttraining and detraining evaluations (T2 and T3); EG = experimental group; CG = control group; BMI = body mass index, a weight-to-height ratio, calculated by dividing one's weight in kilograms by the square of one's height in meters.

2.5. Statistical analysis

Standard statistical methods were used for the calculation of means and standard deviations. The normality and homoscedasticity assumptions were checked respectively with the Shapiro–Wilk and the Levene tests. The training-related effects and detraining analyses were assessed using a two-way ANOVA with repeated measures (groups × time). Results were significant in the interaction ($p \leq 0.05$). A significant F value was observed ($F = 6.0$, $p = 0.000$). A *t*-test for independent samples determined the differences between the groups. A probability-adjusted Student's paired *t*-test was used for pair-wise comparisons. Test–retest reliabilities, as shown by ICC, ranged from 0.90 to 0.93 for all testing exercises. Statistical significance was accepted at $p \leq 0.05$ for all analyses. All data were analyzed using SPSS 17.0.

3. Results

Adherence to training in the EG averaged 91.6 ± 2% (mean of 33 completed sessions of the total of 36 planned sessions). Seventeen and twenty participants in each group respectively started and finished the study. Their main characteristics at baseline are shown in Table 1. Almost all of the participants in this group were able to complete more than 90% of the planned sessions. None of the participants exceeded more than the limit of 3 faults. Reasons for missing sessions were dizziness, feeling unhealthy or too tired (n = 3), falls outside training sessions (n = 1) and hospitalization (n = 1) and other (medical examination or family) (n = 3). No adverse effects or health problems attributable to the testing sessions or prescribed training sessions were noted.

At the beginning of the protocol of high-speed power training, there were no significant differences ($p > 0.05$) observed between groups for anthropometric, strength, power or functional measures. Within each group, no significant changes ($p > 0.05$) in height, weight or BMI were observed (Table 1) between start and finish of the program training (T1–T2). There were no significant differences between the groups at baseline.

The EG showed significant improvements in $1RM_{BP}$ and $1RM_{LE}$ between T1–T2 ($p < 0.05$) (Figs. 1 and 2). Significant main effects for time were observed on $1RM_{BP}$ and $1RM_{LE}$, $F = 14.3$ and 14.7, respectively, $p < 0.05$.

Training-induced changes were also observed in power output measures. CMJ and BT showed improvements between T1 and T2 ($p < 0.05$). Significant main effects for time were observed on CMJ and BT, $F = 16.4$

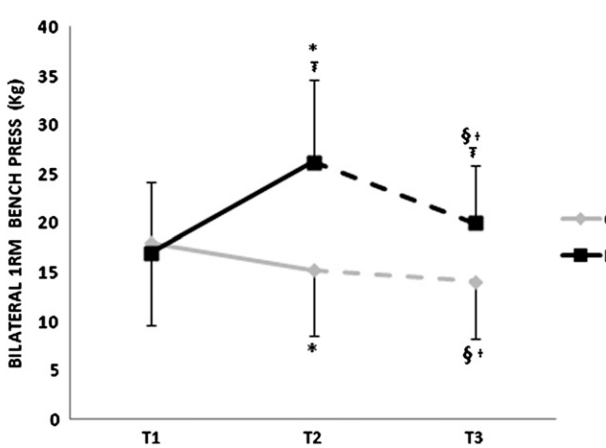

Fig. 1. Bilateral 1RM bench press performance at the beginning of the protocol (T1), after 12-weeks (T2) and after stopping strength training (T3). Data presented are mean ± SD. *Significantly different ($p < 0.05$) from T1–T2 weeks; §significantly different ($p < 0.05$) in detraining from posttraining value (T2–T3). ŦSignificant changes ($p < 0.05$) between the groups; †detraining values significantly different ($p < 0.05$) from pretraining values. EG = experimental group; CG = control group.

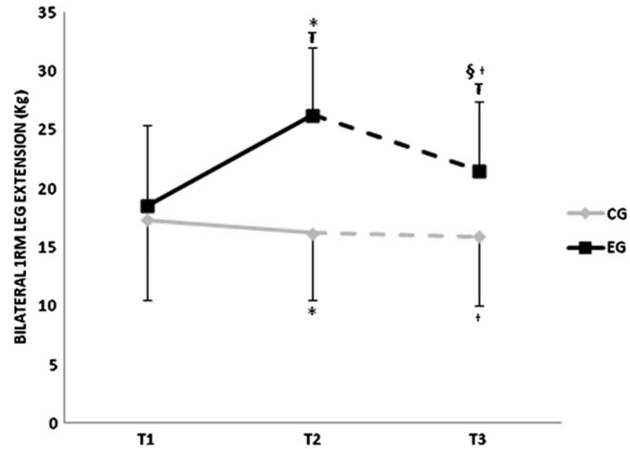

Fig. 2. Bilateral 1RM leg extension performance at the beginning of the protocol (T1), after 12-weeks (T2) and after stopping strength training (T3). Data presented are mean ± SD. *Significantly different ($p < 0.05$) from T1–T2 weeks; §significantly different ($p < 0.05$) in detraining from posttraining value (T2–T3). ŦSignificant changes ($p < 0.05$) between the groups; †detraining values significantly different ($p < 0.05$) from pretraining values. EG = experimental group; CG = control group.

and 5.8, respectively ($p < 0.05$). Functional performance (STS) also increased during the period of training program ($p < 0.05$). Significant group × time interactions were noted for the $1RM_{BP}$, $1RM_{LE}$, CMJ, BT and STS, $F = 11.9$, 12.8, 7.5, 24.5, 10.9, respectively ($p < 0.05$), with EG making significantly greater improvements in performance than CG. Over 12 weeks pre- to post-training, CG decreased significantly their performance, in dynamic strength in upper and lower limbs ($p < 0.05$). Power and functional measures (i.e. CMJ, BT and STS) also showed decreases after training period ($p < 0.05$). There were no significant interaction effects between groups on the BT, $F = 0.1$, n.s.

Nevertheless, significant differences were found between these groups in DT (T39). CG showed reduced performance in all variables from pre- to post-training (−51%) and EG increased 173.6% relative to the start of the training period.

After the 6-week DT period, CG showed reduced performance in all variables (32.9%). Subjects showed significant decreases in CMJ and BT (10–3.6%; $p < 0.05$), respectively. However, significantly lower scores in dynamic strength in $1RM_{BP}$ (9.6%) and functional measures (7.9%) were also observed after the DT period ($p > 0.05$) but $1RM_{LE}$ (1.9%) remained almost unchanged.

EG subjects showed maintenance of power variables after the DT period (Figs. 3 and 4). STS performance test showed only a few decreases (2.8%; n.s.) (Fig. 5), but dynamic strength of both upper and lower extremity muscles showed significant decreases of 23.8% and 18.1% in $1RM_{BP}$ and $1RM_{LE}$, respectively (Fig. 1 and 2). Although EG relative to the training period lost just 43% after DT period. However, total changes in EG between the pre-test and after the DT period showed improvements of 96.4% for all performance tests.

4. Discussion

The primary findings of the present study were that DT may induce larger declines in muscle strength than in power output and preserved physical independence mediated, in part, by the effectiveness of high-speed power training particularly developed for older women. It also suggests that in older populations the velocity at which muscular forces were generated was a critical factor in determining functional performance. Therefore, older women benefit from stimulus at lower percentages of maximal strength (40–75% 1RM; 3×10^{-4} reps), performed at high velocities of muscle contraction. Secondly, our results also demonstrated that muscle power and functional performance gains were not fully lost after training cessation. These results may be related to detraining-induced residual increases in neuromuscular adaptations

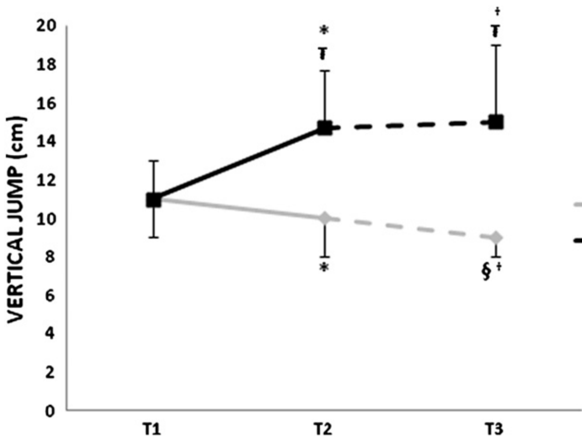

Fig. 3. Vertical jump (CMJ) performance at the beginning of the protocol (T1), after 12-weeks (T2) and after stopping strength training (T3). Data presented are mean ± SD. *Significantly different (p<0.05) from T1–T2 weeks; §significantly different (p<0.05) in detraining from posttraining value (T2–T3). ŦSignificant changes (p<0.05) between the groups; †detraining values significantly different (p<0.05) from pretraining values. EG = experimental group; CG = control group.

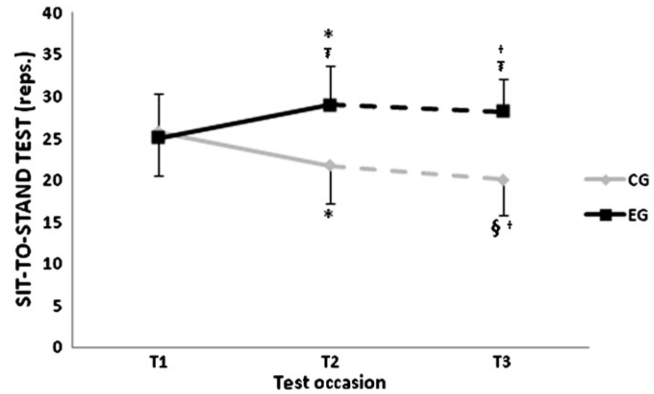

Fig. 5. Sit-to-stand test performance at the beginning of the protocol (T1), after 12-weeks (T2) and after stopping strength training (T3). Data presented are mean ± SD. *Significantly different (p<0.05) from T1–T2 weeks; §significantly different (p<0.05) in detraining from posttraining value (T2–T3). ŦSignificant changes (p<0.05) between the groups; †detraining values significantly different (p<0.05) from pretraining values. EG = experimental group; CG = control group.

above baseline but also to attenuation in functional decline after a high-speed power training. The combination of high-speed and explosive exercises in older women may be an optimal stimulus to 1) induced gains in mechanical muscle function, 2) increases in all components of health-related muscular performance, as well as slowed training cessation decreases in muscle performance, in comparison to a traditional strength training intervention.

As Pereira et al. (2012) reported in a previous study, strength performance resulted in a positive delay transformation rebound in the coordination of functional capacity in STS test. Finally, participants tolerated the intervention well and mean adherence approached 91.6%, probably due to the innovative training adopted.

Compared to detraining, few studies have examined the effects of training cessation (6 weeks) subsequent to a periodized 12-week high-speed power training program in older women. A major finding of this study was that the detraining period resulted in a larger reduction in muscle strength than in muscle power output in the upper and lower extremities. In addition, a preserved functional capacity was observed after the 6-week detraining period. In contrast to the present results, other studies have reported that muscular performance can be maintained over 4–12 weeks of detraining (Harris et al., 2007; Henwood and Taaffe, 2008), if daily activity is maintained.

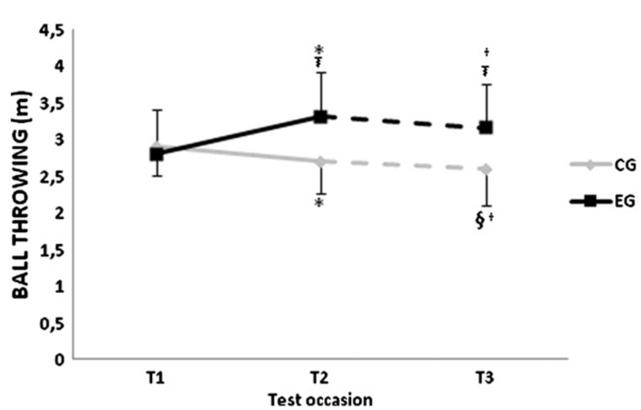

Fig. 4. Ball throwing performance at the beginning of the protocol (T1), after 12-weeks (T2) and after stopping strength training (T3). Data presented are mean ± SD. *Significantly different (p<0.05) from T1–T2 weeks; §significantly different (p<0.05) in detraining from posttraining value (T2–T3). ŦSignificant changes (p<0.05) between the groups; †detraining values significantly different (p<0.05) from pretraining values. EG = experimental group; CG = control group.

The discrepancy between this study and previous studies may be related to the highest level of power of our subjects in comparison with those of other studies (Henwood and Taaffe, 2008; Saez Saez De Villarreal et al., 2010), as well as the impact from prior specific high speed power training. A unique finding of the present data may suggest the important role of neuromuscular adaptation for strength and power resulting in a greater magnitude of responses during detraining periods (Häkkinen et al., 2000). These could be related in part to a better recruitment and more economical use of motor units and to reduction of the inhibitory inputs to the alpha motor neurons (Kannus et al., 1992). It may also be related to optimized recruitment of fast twitch fibers of the trained muscles which can generate four times the power output of type I fibers (Lexell, 1995). Nevertheless, the advantage of performing high-speed power training instead of maximal strength appears to lie in the higher preservation of muscle power output achieved. Consequently, it may also help prevent falls (Aagaard et al., 2010; Tam and Gordon, 2003), leading to greater dependence and functional capacity. This is crucial to improved knowledge of the specific physiologic mechanisms in functional adaptation, since muscle power is also a more discriminant predictor of functional performance in older adults than muscle strength (Reid et al., 2008). Upper body strength values showed a higher rate of decrease during DT period compared to lower limbs over the same period. The differential changes in activity patterns between upper and lower muscles and perhaps the lesser strength in the arms compared to the legs (Aoyagi and Shephard, 1992) seem to be the cause of such difference in older women. In agreement with previous studies (Bottaro et al., 2007; Henwood and Taaffe, 2008) CG showed significant decreases in arm extension (9.6%) and only minor decreases (1.9%; n.s.) in leg extension. For daily activities, this is sufficient to ensure proper muscle performance with aging in older women, but such maintenance tends to decline less strongly in lower limbs compared to upper limbs. In contrast the present results showed that after high-speed power training CMJ height in EG remains somewhat higher (though not significantly so at 2.0%) while no significant decreases were observed in BT (−4.5%; n.s.). Thus, to prevent losses it may be that reduced frequency and intensity are required to maintain the muscle strength benefit from an exercise period (Izquierdo et al., 2005).

An interesting finding was also related to the fact that, despite strength losses, EG still showed better results in all tests at baseline performance. This may suggest a greater adaptive plasticity in skeletal muscles and neuromuscular system of older women in response to high-speed power training compared to that observed after a classical strength training intervention. Consequently, it may be possible to retain training-induced gains after a detraining period if high-speed power

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training is planned as a therapeutic intervention for preserving mobility and independence among older people. It also means that an occasional missed exercise session or temporary cessation of habitual exercise should not be a cause for concern in exercising older women. A possible limitation of the present study was the difficulty in comparing it with other studies. Subject age varied greatly and the baseline level of fitness was for the most part unknown. In addition, the discrepancy between results in DT period may be due to duration of the training cessation. However there was no way of preventing individuals from engaging in more physical activity during this period. Excluding the fact that significant decreases were observed in some measures such as dynamic strength. It suggests that subjects were mainly able to comply with these restrictions.

The present findings suggest that training cessation up to 6 weeks is sufficient to induce significant losses in dynamic strength in $1RM_{BP}$ and $1RM_{LE}$, but to some extent functional capacity, and especially explosive force, may be preserved after high-speed power training. The data support the use of RT programs with high velocity and low volume in older women to promote autonomy and muscle performance enhancement with advancing age. This investigation was also useful in highlighting an innovative type of training, suggesting new ways to optimize muscular performance in older populations, and thus to reduce detraining effects.

5. Practical applications

Aggregating muscle strength, power and functional task measures across the natural life of women will be important for young people and for the development of future studies. To address this task, future programs of RT in older women must make use of rigorous designs, assessment tests to evaluate disability, and monitor these with specialized professionals. Appropriate training programs must also be planned, to provide for different participants, particularly those with preexisting functional limitations and disabilities in the home. However, care must be taken when implementing these types of training program and exercise regimen in medically fragile populations since some studies do not report all resultant injuries and adverse events.

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