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Title Page

Why Fast Velocity Resistance Training Should be Prioritized for Elderly People?

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Abstract

Due to recent demographic changes with a greater proportion of elderly people in the world, physical independence among older adults is becoming increasingly more important. This mini-review summarizes and discusses neuromuscular adaptations in response to resistance training with different contraction velocities in untrained elderly. Slow ("hypertrophic type") and fast velocity ("power/explosive type") training can to a similar extent improve muscle mass and maximal force in untrained elderly. However, fast velocity resistance training is superior for improving power output, explosive force, and functional capacity (i.e., the ability to perform activities of daily living). Thus, fast velocity resistance training provides more efficient neuromuscular adaptations, increasing simultaneously strength, power, explosive force, muscle mass, and functional capacity of untrained elderly.

Keywords: Ageing, Explosive force, Functional capacity, Maximal strength, Muscle mass, Muscle power, Power training, Strength training.

Introduction

Aging is gradually associated with inevitable impairment of the neuromuscular system (36,37) including muscle atrophy and loss of maximal strength, muscle power output, and explosive force (33,35,52). Regular physical activity is essential to delay these deleterious effects of aging (29). Specifically, resistance training is an effective type of training that can effectively enhance maximal strength (41), muscle power output (8), explosive force (25), and skeletal muscle mass (42) in elderly, with important implications for health and functional capacity. For example, explosive force and power output are related to functional capacity (8,38) and balance (28,43). By contrast, age-related exacerbated muscle atrophy is associated with functional impairment and physical disability (30), and strength is independently associated with risk of death from all causes and cancer in men (51).

Specificity of the resistance training program influences enhancement of muscle strength, power output, explosive force, and skeletal muscle mass (31). Contraction velocity and training intensity are two basic variables to manipulate when designing resistance training programs. Fast velocity training is typically characterized by the intention to contract as fast as possible in the concentric portion and slow to moderate velocity training is often performed as slow concentric and eccentric contractions of 2-3 s (8). Training intensity can be divided in to low (<60%), low/moderate, (60-69%), moderate/high (70-79%), and high (≥80% of one-repetition maximum - 1-RM) (41). For older adults, recent meta-analyses and the ACSM recommends moderate load and slow to moderate velocity training for increased muscle strength and muscle mass (5,13,41,48). However, these recommendations for strength improvements were defined based on intervention studies with older adults using slow velocity contractions. These studies do not discuss whether fast velocity contraction would be as effective as slow to enhance maximal strength and muscle mass in this population, as observed in young adults (18,26). In addition, for improvement of power output, there is a consensus that light to moderate load fast velocity training is more effective than slow velocity training for older adults (8,48). Moreover, for explosive force, moderate to heavy loads with intention to contract as fast as possible are recommended for this population (25) and conversely, slow velocity training seems to be less effective (58). However, in terms of resistance training recommendations for people above 60 years of age, non-specific effects are also important to consider, e.g., influence of slow to moderate velocity training on power output and explosive force, as well as the influence of fast velocity training on maximal strength and muscle mass, in the context of how such adaptations can translate into functional improvements. For older adults, improving as many of these qualities as possible may be desired to optimize independence and quality of life.

This mini review discusses improvements of muscle strength, power output, explosive force, muscle mass, and functional capacity following resistance training with different contraction velocities (i.e., slow velocity "hypertrophic type" vs. fast velocity "power/explosive type") in older adults. The discussion helps to qualify choices made in the design of resistance training programs for this population.

Training characteristics and adaptations

Several studies have compared resistance training with slow vs. fast contraction velocity, while others investigated only fast or slow velocity separately. Prescription of training variables (frequency, exercises, intensity, sets, repetitions, volume, rest interval, and velocity) vary in each of the studies and it is detailed in Table 1 for slow velocity and Table 2 for fast velocity training. Note that studies using slow velocity training prescribed actions of 2 or 3 s duration for both concentric and eccentric phases. Conversely, studies investigating fast contractions reported that the concentric action was performed with the intention to contract as fast as possible, but the eccentric action was similar to slow velocity prescription, with 2 or 3 s of duration. Importantly, when training intensity is increased, contraction velocity is reduced – due to the inherent nature of the force-velocity relationship - even if the intention is to contract as fast as possible (24). The same occurs with increased fatigue, with contraction velocity reducing at the end of sets or the training session (40).

Based on the studies included in the present review, Figure 1 depicts the adaptations of slow and fast contraction resistance training in elders' maximal strength, peak power output, explosive force, muscle hypertrophy, and functional capacity outcomes. The intention is to summarize results across studies and ease the comparison of slow and fast training in elderly. Before drawing conclusions, the reader should bear in mind that these studies have individual resistance training variables prescription (other than training velocity) that can influence training adaptations. Moreover, because the included training studies have varying length of training period, normalizing for time (Δ%/weeks) is important to compare studies, although bearing in mind that the response may not be completely linear over time and level off after some months (31).

*****Table 1 here*****

*****Table 2 here*****

*****Figure 1 here*****

Maximal strength

For strength increases of novice (untrained) and intermediately experienced (at least 6 months of resistance training experience) older adults, the ACSM suggests the use of slow to moderate velocity and 60–80% of 1-RM (48). A recent meta-analysis (5) suggested more specifically 70-79% of 1-RM and a slow time under tension of 6 s per repetition. However, studies comparing the effects of slow velocity and moderate load vs. fast velocity and light to moderate load show that this is not the only way to increase maximal strength in elderly. Thus, significant increases for dynamic (3,6,17,20,27,34,45) or isometric maximal strength (27,34) occurred for both fast and slow velocity groups. Similar results are also observed in studies evaluating only slow velocity (56–58) or fast velocity (12,15,44,47,49). The weekly improvements of dynamic strength seem to be similar between slow and fast velocity (1.95±0.90 and 2.16±0.94%, respectively), however, for isometric maximal strength, there is a trend for fast velocity training to be more efficient (1.23±0.52 and 1.80±0.86%, respectively) (Figure 1).

Neural factors and muscle cross sectional area are related to maximal strength output (48). However, for untrained elderly and young adults, neural adaptations following resistance training have greater influence than muscle hypertrophy for strength increases (7,9,57). Both fast and slow contractions are capable of enhancing maximum voluntary activation levels, but fast contractions elicit a greater motor unit activation level - in spite of the relatively lower intensity - than slow contractions (19). There are also evident differences in the surface electromyography amplitude between slow and fast contractions of the same external load (11,55). Consequently, moderate to high intensity resistance training executed as fast as possible would result in greater improvements than equivalent-intensity slow resistance training. Recent meta-analyses suggested that strength increments can be optimized training with 70–79 % of 1-RM and time under tension of 6 s per repetition in elderly, but this analysis did not take into consideration the velocity of training (5). Importantly, fast contractions at higher intensities appear to provide greater increases in strength compared with lower intensities (8).

Muscle power output

Recommendations for power output improvements include the use of light to moderate loading (30–60% of 1-RM) and fast velocity contractions (8,48). Thus, in contrast to maximal strength and muscle mass which are stimulated efficiently at either slow or fast velocity of contraction, muscle power adaptations are optimized by using faster velocity of contraction (8,54). Direct comparisons show an advantage of fast velocity training compared with slow velocity for power enhancement in older adults (6,17,27,45). The effect of slow velocity training in power are contradictory, with some studies reporting increased power output (3,6,20,27,45) and others not (17,56,58) (1.06±0.86% per week). However, there is a consensus that faster velocity of training with a wide range of intensities (30–85% of 1-RM) results in greater power improvements (2.20±1.34% per week) (3,6,12,15,17,20,27,44,45,47,49).

Muscle power output is the product of force and velocity of muscle contraction. It was reported in young subjects that training with maximal intended velocity has great influence in power improvements due to increases in both maximal force, rate of force development (32), the velocity that the muscle is activated (i.e., rate of electromyography rise) (16) and shortened (1,50). On the other hand, while slow velocity training has positive effects on muscle force, the effects are more limited in regards to faster muscle activation and shortening ability in young subjects (2,4) and untrained elderly (58). There is a marked difference between fast and slow training in the power output capacity (54). Nevertheless, it seems that fast velocity training either with higher or lower intensities provides similar increases in power output in elderly (8). Thus, focusing on contracting as fast as possible regardless of the actual external load seems to be the key.

Explosive force (rate of force development)

Training with the intention to contract muscles as fast as possible is effective for improving explosive force, i.e., rate of force development measured during static contraction (25). Only few studies investigating explosive force adaptations following slow velocity training among elderly exist, and show none or only minimal improvements with this velocity and moderate training intensity (0.03±1.63% per week) (17,34,58). In contrast, fast velocity resistance training results in large increases of explosive force (4.31±3.32% per week), exceeding even power improvements in older persons (12,15,17,34,44).

For a great explosive force production, a basic requirement is that the nervous system activates as many motor neurons as possible with the highest possible firing frequency at the onset of contraction. Studies investigating neuromuscular adaptations underlying explosive force improvements have been performed preferentially in young adults (2,4). Resistance training composed of fast contractions can positively influence explosive force by increasing neural drive (4), and by increasing maximal strength (2). On the other hand, slow contractions and moderate load resistance training are not as effective as fast contractions to increase fast muscle activation (4). Thus, increases in explosive force in the later phase of contraction (e.g., 200 ms from onset) can effectively be achieved with maximal strength adaptations (2,4).

Muscle hypertrophy

For muscle hypertrophy of older adults with novice and intermediate level experience in resistance training, the ACSM recommendations are the same as for maximal strength: moderate loading (60–85% of 1-RM) and slow to moderate velocities (48). However, this is not the only way to achieve muscle hypertrophy. Few studies have compared the effects of slow velocity (2-3 s concentric and 2-3 s eccentric) and moderate load (50-85% of 1-RM) against fast velocity (concentric as fast as possible or plyometric) and light to moderate load (30–85 % of 1-RM) for muscle hypertrophy in elderly (17,27). These studies found significant increases of muscle or lean mass during the intervention period without significant differences between groups. Some studies have evaluated only slow velocity (56–58) or fast velocity resistance training (15,44,49). Based on these studies, slow and fast velocity methods showed similar increases of 0.94±1.33 and 1.00±1.26% per week of training.

Hypertrophic muscular adaptations can be attained with mechanical and metabolic stresses following resistance training (21–23). Compared to neural factors, hypertrophy has smaller influence in strength increase of untrained elderly (9,10,39,57). Therefore, muscle mass increases would not be the major determinant for increased function observed during resistance training in elderly novice practitioners. However, there is no doubt about the metabolic and endocrine benefits of skeletal muscle mass (53). In addition, lower levels of skeletal muscle mass are associated with functional impairment and physical disability. Thus, improvements of muscle mass should also be prioritized in the training prescription. In this regard, fast velocity training seems as effective as slow velocity training but as the total load is an important stimulus to increase muscle mass, slow contractions using higher loads could also be combined with low loads of higher velocity across the training periodization.

Functional capacity

Maximal strength, power output, explosive force, and skeletal muscle mass influence functional capacity (i.e., the ability to perform activities of daily living, e.g., walking, seating, stair climbing) (8,30,38), and simultaneous improvements in these qualities would therefore be beneficial for functional improvements. Improvement of functional capacity tests (e.g., timed up and go, walking speed, stair ascent and descent, 30-s sit to stand) among elderly have been observed in a wide variety of fast velocity resistance training studies (3,6,14,17,27,34,44–46,49). Some studies investigating slow velocity with moderate load training also found increases of functional capacity (3,17,27,45). However, other studies did not, even when strength and/or muscle mass increases were observed (6,34,56). Comparing the different training velocities, studies using slower velocities showed a smaller increase in functional capacity compared with faster velocity (0.56±0.43 and 1.37±1.15% per week, respectively). Thus, the greater increases in power output and explosive force observed during fast velocity training seems to influence functional capacity in a higher magnitude compared to maximal strength increases alone. A plausible reason for this is that daily living activities are most often performed in repeated circles of acceleration and deceleration, and not as slowly controlled contractions.

Concluding remarks

This mini review provides evidence that slow (i.e., hypertrophic type) and fast velocity (i.e., power or explosive type) training can similarly improve muscle mass in untrained elderly. However, compared with slow velocity, training at fast velocity using similar loads induces greater improvements in maximal force and greater improvements in power output, and explosive force of untrained elderly. These adaptations lead to more efficient development of functional capacity following fast velocity training. Thus, fast velocity training is more beneficial than slow velocity training for neuromuscular and functional improvements in untrained elderly. Most of the studies used seated leg press, knee extension, and leg curl, however, other lower limbs exercises, such as squat variations, calf raise, and plyometric training have also shown to be effective (Tables 1 and 2).

Despite power/explosive training being a safe and efficient method for older persons (9), the personal trainer should take certain caution when prescribing this type of training. Before employing fast velocity contractions in the resistance training program, the personal trainer should check existing musculoskeletal disorder that may be worsened by this type of training (especially plyometric training). For example, does the client have a history of disc prolapse, whiplash, severe arthritis, radiating pain etc. Thereafter, ensure that the client performs the respective exercises with proper technique. For beginners in resistance training, it may be more feasible and safe to use exercises such as knee extension, seated leg curl, and seated leg press, with free weight exercises performed only using slow and controlled contraction velocity. Free weight exercises using fast velocity and plyometric exercises could be performed by intermediate to advanced clients, because it requires good dynamic balance and therefore inherently increases the risk of falling during exercise. Even so, the personal trainer should evaluate the readiness of each individual to perform this type of training. During exercises requiring dynamic balance, safety strategies (e.g., holding a stable structure or close monitoring by the personal training) should be taken. Plyometric training is characterized by a fast concentric preceded by a fast eccentric action that increases subsequent muscle damage and soreness, requiring a longer recovery period between training sessions. Moreover, acutely induced resistance training-related muscle damage can decrease functional capacity and increase risk of falling in elderly during the recovery period (40).

A safe power/explosive training session for elderly subjects should be performed during full supervision (47) and begin with a proper general and specific warm-up and dynamic mobility exercises with the aim of reducing the risk of musculoskeletal injuries. Training volume as well as intensity should be increased progressively, where a single set per exercise per session can be effective for beginners (44), with gradual introduction of more sets to ensure continuous adaptations. Moreover, the use of non-failure resistance training seems to optimize neuromuscular adaptations for this population (39), whereas repetitions to concentric failure can increase cardiovascular risks (promote greater increases in heart rate and blood pressure) (10). In addition, starting with light to moderate loads of 30–60% of 1-RM in untrained elderly and increasing loads progressively to ~85% of 1-RM to ensure safety and adherence (40). Concerning rest interval between sets, studies suggest that 60-180 s is adequate for recovery (Table 2). However, longer rest intervals will allow greater neuromuscular recovery (lower fatigue), leading to greater performance in the subsequent sets. Nevertheless, the personal trainer should balance this against the often limited time available with each client. Optimal recovery time between power/explosive type training sessions in elderly remain unclear. However, it seems that individuals respond differently (40) and the personal trainer should closely monitor progression of each client to be able to individually adjust the training program.

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Figure captions

Figure 1. Summary of the studies examining the improvements (normalized per weeks of training, i.e., percentage improvement per week) in maximal strength (1-RM and isometric), peak power output, explosive force, muscle hypertrophy, and functional capacity after slow velocity (white scatter dots) or fast velocity (black scatter dots) resistance training in untrained elderly people. Maximal strength, 1-RM: slow (3,6,17,20,27,45,56–58) and fast (3,6,14,17,20,27,45,47,49) velocity; Isometric: slow (20,27,34,56–58) and fast (12,14,27,34) velocity; peak power output: slow (3,6,17,20,27,45,56,58) and fast (3,12,15,17,20,27,45,47,49) velocity; Explosive force: slow (17,34,58) and fast (12,15,17,34) velocity; Muscle hypertrophy: slow (17,27,56–58) and fast (15,17,27,49) velocity; Functional capacity: slow (3,6,17,27,34,45,56) and fast (3,6,14,17,27,34,45–47,49) velocity.

Table. 1. Summary of slow velocity resistance training design.

Study	Sample	Age (years)	Duration (weeks)	Frequency (days/week)	Lower limbs exercises	Intensity	Sets	Reps	Rest interval	Velocity
Balachandran et al. (3)	n=9 (♀=8 and ♂=1)	71 ± 8.2	15	2	Leg press, leg curl, hip adduction and calf raise	70% of 1-RM	3	10-12	60-120 s	Con: 2 s Ecc: 2 s
Bottaro et al. (6)	n= 9 (♂)	66.3 ± 4.8	10	2	Leg press, knee extension and knee flexion	40-60% of 1-RM	3	8-10	90 s	Con: 2-3 s Ecc: 2-3 s
Correa et al. (17)	n=14 (♂)	67 ± 5	6	2	Leg press, knee extension and knee flexion	RM	3-4	8-12	120 s	Con: 2 s Ecc: 2 s
Fielding et al. (20)	n=15 (♀)	72.1 ± 1.3	16	3	Leg press and knee extension	70% of 1-RM	3	8	NR	Con: 2 s Ecc: 2 s
Henwood et al. (27)	n=19 (♀=9 and ♂=10)	69.6 ± 1.1	24	2	Leg press, prone leg curl and leg extension	75% of 1-RM	3	8	60 s	Con: 3 s Ecc: 3 s
Lopes et al. (34)	n=14 (♀)	69 ± 7.3	12	3	Horizontal leg press, knee extension, knee flexion, plantar flexion in the step, abductor and adductor machines	60% of 1-RM and RM.	3	8	60 s	Con: 2 s Ecc: 2 s
Ramirez-Campillo et al. (45)	n=15 (♀)	68.7 ± 6.4	12	3	Leg press, prone leg curl and leg extension	75% of 1-RM	3	8	60 s	Con: 3 s Ecc: 3 s
Walker et al. (57)	n=26 (♂)	65 ± 4	10	2	Leg press, knee extension and knee flexion	60-85% of 1-RM	2-5	8-14	60-120 s	Con: 2 s Ecc: 2 s
Walker et al. (58)	n=27 (♂);	65±4	20	2	Leg press, knee extension and knee flexion	60-85% of 1-RM	2-4	8-14	60-120 s	Con: 2 s Ecc: 2 s
Walker et al. (56)	n=81 (♀=46 and ♂=35)	♀=68.6 ± 2.0 ♂=69.8 ± 2.4	12	2	Leg press, knee extension, knee flexion and seated calf-raise	50-60% of 1-RM	2 3	16-20 14-16	30-240 s	Con: 2 s Ecc: 2 s

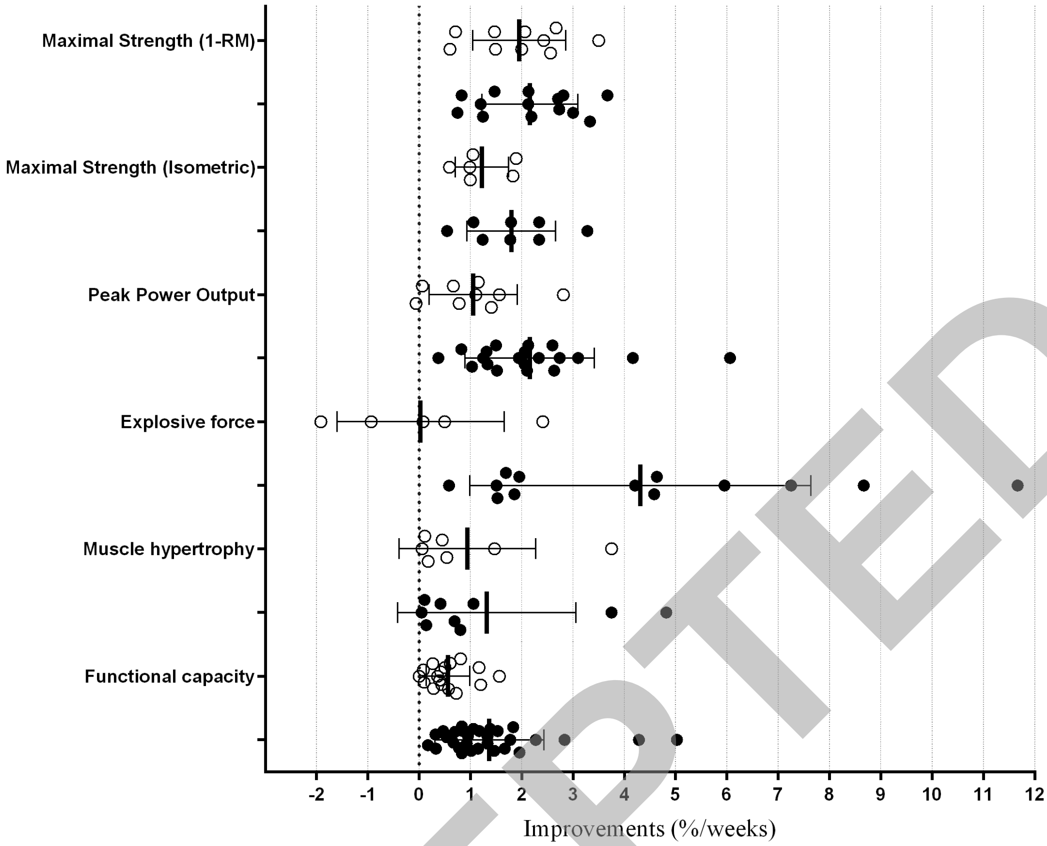
Reps, repetitions per set; RM, repetition maximum; NR, non-reported; Con, concentric; Ecc, eccentric.

Table. 2. Summary of fast velocity resistance training design.

Study	Sample	Age	Duration (weeks)	Frequency (days/week)	Lower limbs exercises	Intensity	Sets	Reps	Rest interval	Velocity
Balachandran et al. (3)	n=8 (♀)	71.6 ± 7.8	15	2	Leg press, leg curl, hip adduction and calf raise	50-65 % of 1-RM	3	10-12	60-120 s	Con: AFAP Ecc: 2 s
Bottaro et al. (6)	n= 9 (♂)	66.3 ± 4.8	10	2	Leg press, knee extension, knee flexion	40-60% of 1-RM	3	8-10	90 s	Con: AFAP Ecc: 2-3 s
Conlon et al. (14,15)	Non-periodized group, n=10 (♀=6; ♂=4)	70.4 ± 6.1	22	3	Seated leg press, seated leg-curl, and leg extension	RM	3	10	90-120 s	Con: AFAP Ecc: 2 s
	Block periodization group, n=13 (♀=6; ♂=7)	71.8 ± 5.4	22	3	Seated leg press, seated leg-curl, and leg extension	RM	3	5, 10 or 15	90-120 s	Con: AFAP Ecc: 2 s
	Daily-undulating periodization group, n=10 (♀=5; ♂=5)	71.2 ± 4.2 y	22	3	Seated leg press, seated leg-curl, and leg extension	RM	3	5, 10 or 15	90-120 s	Con: AFAP Ecc: 2 s
Correa et al. (17)	Power training group, n=13 (♂)	67 ± 5	6	2	Leg press, knee extension and knee flexion	RM	3-4	8-12	120 s	Con: AFAP Ecc: 2 s
	Rapid strength training group, n=14 (♂)	67 ± 5	6	2	Lateral box jump, knee extension and knee flexion	RM and box height (10-30cm)	3-4	8-12	120 s	Con: AFAP Ecc: 2 s
Fielding et al. (20)	n=15 (♀)	73.2 ± 1.2	16	3	Leg press and knee extension	70% of 1-RM	3	8	NR	Con: AFAP Ecc: 2 s
Henwood et al. (27)	n=19 (♀=12; ♂=7);	71.2 ± 1.3	24	2	Leg press, prone leg curl and leg extension	40-75% of 1-RM	3	8-10	60 s	Con: AFAP Ecc: 3 s
Lopes et al. (34)	n=12 (♀)	67 ± 7.4	12	3	Horizontal leg press, knee extension, knee flexion, plantar flexion in the step, abductor and adductor machines	40-80% of baseline 1-RM	3-4	8	180 s	Con: AFAP Ecc: 2 s
Radaelli et al. (44)	Low volume group, n=13	64.8 ± 3.2	12	2	Knee extension, bilateral leg curl, hip abduction, and hip adduction	30-60% of 1-RM	1	8-12	180 s	Con: AFAP Ecc: 2-3 s
	High volume group, n=13	66.2 ± 2.4	12	2	Knee extension, bilateral leg curl, hip abduction, and hip adduction	30-60% of 1-RM	3	8-12	180 s	Con: AFAP Ecc: 2-3 s
Ramirez-Campillo et al. (45)	n=15 (♀)	66.3±3.7	12	3	Leg press, prone leg curl, leg extension and CMJ*	40-75% of 1-RM	3 2*	8 3*	60 s	Con: AFAP Ecc: 3 s
Ramirez-	Two-times/week	70.0±6.9	12	2	Leg extension and CMJ*	75% of baseline	3	8	60 s	Con: AFAP

Campillo et al. (46)	group, n=8 (♀)					1-RM		4*		Ecc: 3 s
	Three-times/week group, n=8 (♀)	71.9±6.3	12	3	Leg extension and CMJ*	75% of baseline 1-RM	2	8 4*	60 s	Con: AFAP Ecc: 3 s
Ramirez-Campillo et al. (47)	High supervision group, n=30 (♀)	67.5 ± 5.3	12	3	Leg press, prone leg curl, leg extension and CMJ*	40-75% of baseline 1-RM	3 2*	8 3*	60 s	Con: AFAP Ecc: 3 s
Reid et al. (49)	Low intensity group, n=25 (♀=15 and ♂=10)	78.3±5	16	2	Seated leg press and seated knee extension.	40% of 1-RM	3	10	NR	Con: AFAP Ecc: 2 s
	High intensity group n=27 (♀=18 and ♂=9)	77.6 ± 4	16	2	Seated leg press and seated knee extension.	70% of 1-RM	3	10	NR	Con: AFAP Ecc: 2 s

Reps, repetitions per set; RM, repetition maximum; AFAP, as fast as possible; NR, not reported; *different sets and repetitions number for specific exercise; CMJ, countermovement jump; Con, concentric; Ecc, eccentric.


Maximal Strength (1-RM)
Maximal Strength (Isometric)
Peak Power Output
Explosive force
Muscle hypertrophy
Functional capacity
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
Improvements (%/weeks)