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RESISTANCE TRAINING FOR MUSCLE STRENGTH AND LEAN MASS IN ADULTS OLDER THAN 60 YEARS – A SYSTEMATIC REVIEW

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Keywords:
Resistance training; Body Composition; Sarcopenia; Older adults.

Abstract

Objectives: Verify the effect of resistance training (RT) in muscle mass and muscle strength in older adults. **Methods**: Randomized Controlled Trials (RCT) published between 2005 and 2015, with a study population aged 65 and up that went through an RT based intervention were analysed. Body composition should be assessed by Dual Energy X-ray Absorptiometry or Computed Tomography Scan. Internal validity of each article was assessed using the PEDro scale. **Results**: Five RCTs whit score of 5/10 met the inclusion criteria and globally 162 participants were assessed. Each study was based on a RT program of 6-16 weeks of 2-3times/week. **Discussion** Main results show that high intensity and even low intensity RT, increased muscle mass, cross sectional area, strength of the quadriceps and functionality. RT has shown great outcomes in preventing sarcopenia. Results magnitude is proportional to RT characteristics.

Introduction

Sarcopenia, first coined by Irwin Rosenberg in 1989, is now accepted to describe the involuntary loss of skeletal muscle mass and muscle strength and function during aging[1]. Is a complex medical condition that leads to loss of independence, high risk of falls, decreased quality of life, increased expenses in health and possibly increased mortality[2].

Rate of loss is estimated to be 1%–2% per year after the age of 50, especially in the lower limbs, in conjunction with strength declines of 1.5% per year that accelerates to 3% annually after the age of 60. These losses result in a decreased total muscle cross sectional area (CSA) of approximately 40% between 20 and 60 years of age [1]. While this decline occurs gradually in men, it is quite rapid in women, especially after menopause [2]. It has been estimated that up to 5%-15% of people older than 65 years and 11% - 50% of people older than 80 years have sarcopenia [1,3]. Some data reports that 53% males and 43% females older than the age of 80 were sarcopenic [1].

Sarcopenia can be considered 'primary' (or age-related) when no other cause is evident but aging itself, or 'secondary' when one or more causes are evident. In general, etiology of sarcopenia is multi-factorial becoming difficult to characterize each individual as having a primary or secondary condition. This situation is consistent with recognizing sarcopenia as a multi-faceted geriatric syndrome [4].

Multiple factors appear to be involved in the development of this condition including loss of muscle fibers (mainly type II), changes in muscle fiber quantity and quality, protein synthesis rates, inflammation and altered hormonal levels [1,5].

Two other major risk factors are under-nutrition and obesity [6]. Female gender or some organ diseases, such as cancer, hypoxia-related diseases, diabetes mellitus II, kidney disease and/or kidney failure and HIV may be predisposing factors to sarcopenia [2,6]. Several authors agree that the most prominent cause of sarcopenia is physical inactivity [3,6].

At present there are no standardized diagnostic criteria for sarcopenia, although the following criteria could be used: walking speed below 0.8 m/s in the 4 meter walking test, decreased handgrip strength below 26kg in males or 16kg

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in females, a distance in six minutes' walk test lower than 400 m and specially low appendicular lean mass [7,8]. Reference values depends on population and assessment methodologies, especially for muscle mass [9].
A growing body of evidence indicates that physical activity can slow sarcopenia and recent evidence on RT seems to support earlier research showing that RT may be the most effective strategy to prevent or/and treat sarcopenia through muscle hypertrophy and increased muscular strength and power [1].

The purposes of this systematic review were to verify the effect of RT, in adults older than 60 in muscle strength and lean mass.

Materials and methods

This systematic review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [10] to conduct this review. A bibliographic database search of PubMed, PEDro and Cochrane Library was performed to identify RCTs of Resistance Training (RT) or Strength Training (ST) in older adults (age 60 and up) with no prior exercise training and with assessment of body composition performed by DEXA, CT scan, ultrasonography or magnetic resonance image (MRI), published between 2005 and 2015 in English, French, Portuguese or Spanish. RCTs where study population have diagnosis of Diabetes Mellitus type II, Cancer, Obesity or Osteoporosis and studies with included diet, nutrition, medication or supplements in the intervention or interventions not based only in RT were not eligible for analysis (exclusion criteria).

Study Selection

Selection of studies was performed by two of the reviewers, to avoid the exclusion of relevant articles. When the reviewers did not reach a consensus, other independent reviewer was contacted.

PEDro scale for assessing RCTs has sufficient reliability to be used in systematic reviews. It should be applied by more than one reviewer individually, followed by a discussion in order to analyse the results and see the level of agreement between the assessors [11].
This scale includes criteria of internal validation assessment and statistical analysis. Each satisfied item adds 1 point to the total score; with the exception of item one, as it assesses external validity. If the criterion is not met, then no points are added.
In this systematic review, four independent reviewers (SFC, CG, MA, and SMC) read and evaluated the 5 studies in accordance with the PEDro scale. When a consensus was not reached, consultation by an independent reviewer (MLR) was required.

Results

A total of 340 manuscripts were found (figure 1). After applying all the inclusion and exclusion criteria and excluding all the duplicates a total of 5 RCTs were analysed.

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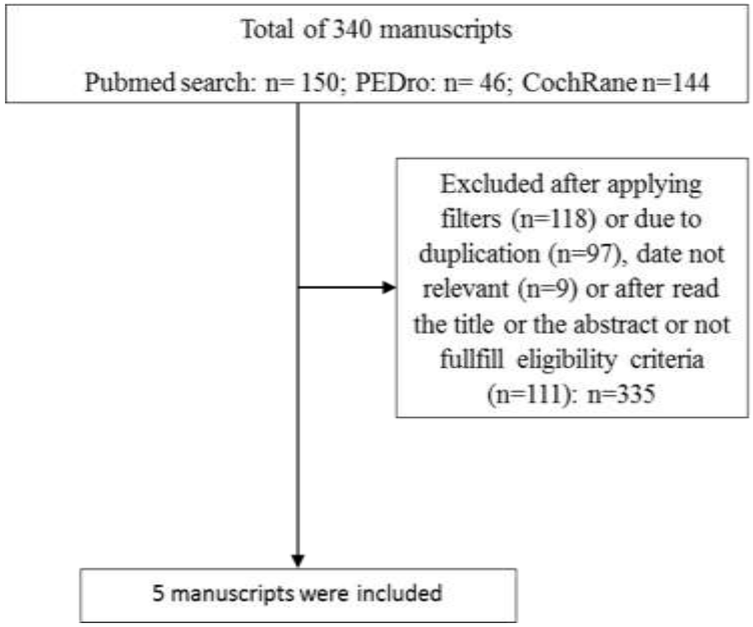

Figure (1): Flowchart for selection of papers

All five studies selected for the review were RCTs published in English and released between 2009 and 2014.

A final PEDro score of 5/10 for all studies was obtained (table 1), which according Maher et al [11] is of "moderate reliability", which indicates that the results tend to show greater effects of intervention than it really is.

Table 1 – The PEDro scale summary of included studies

Criteria	(Bickel *et al.*, 2011)	(Fragala *et al.*, 2014)	(Scanlon *et al.*, 2014)	(Mueller et al., 2009)	(Watanabe et al., 2014)
1	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes	Yes
3	No	No	No	No	No
4	Yes	Yes	Yes	Yes	Yes
5	No	No	No	No	No
6	No	No	No	No	No
7	Yes	No	No	No	No
8	No	Yes	Yes	Yes	Yes
9	No	No	No	No	No

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10	Yes	Yes	Yes	Yes	Yes
11	Yes	Yes	Yes	Yes	Yes
Total score	5/10	5/10	5/10	5/10	5/10

A total of 201 participants were analysed (Table 2) but only 162 participants were included, as one trial [12] included young and older participants (39 of the 70 participants in this study were outside the age criterion). All trials except one [12] analysed subjects of both genders, with ages over 60 years [12]. Although our PICO question (Population, Intervention, Comparator and Outcome) included participants with age over 65 years and some studies presented some participants with 60 years, it was not exclusion criterion, as the rest of the sample in the study covered the inclusion criteria (RCTs median age was superior to 65 years).

There was a considerable diversity in the frequency, intensity, and duration of interventions (Table 3). Some studies recommend RT frequency of twice a week [13–16] and only one study suggested a frequency of three times per week [12]. Duration of different exercise training programs varied between 6 weeks [13,15], 12 weeks [14,16] and 48 weeks [12]. Three of the studies [12–14] followed the recommended guidelines for older adults by the American College of Sports Medicine [17].

Two studies [13,14] reported supervision in exercise training program by a certified strength and conditioning specialist. Others exercise training programs were supervised by one coach per two participants [16], or a direct supervision from a clinical exercise physiologist [12]. In one study the level of supervision was unclear [15].

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Table 2 – Characteristics of different samples of analysed studies.

Reference	Sample Characteristics Population; Number studied (M/F); Age (y) (Mean ± SD) [Range]	Strength Characteristics	Body Composition Characteristics
Mueller et al. 2009	Men & women with stable medication and health conditions; Group RT: *n* = 23 (10/13); (80.1 ± 0.8 y) Group EET: *n* = 23 (10/13); (80.3 ± 0.7 y) Group CT: *n* = 16 (6/10); (81.8 ± 0.8 y)	***Maximal isometric extension of the legs (Nkg^{-1})*** Group RT: Baseline – 15.3 12 weeks – 15.8 Group EET: Baseline – 14.8 12 weeks – 16.1 Group CT: Baseline – 15.7 12 weeks – 15.1	***Body fat mass (kg)*** Group RT: Baseline – 19.1 12 weeks – 19.0 Group EET: Baseline – 17.6 12 weeks – 16.7 Group CT: Baseline – 18.9 12 weeks – 19.1
Bickel et al. 2011	Community-dwelling; Group 1: *n* = 31; (64.1 ± 0.6 y) [60-75] Group 2: *n* = 39; (27.5 ± 0.6 y) [20-35]	***Knee extension 1RM (kg)*** Phase 1: Group old: Baseline – 36.9 ± 2.1 16 weeks – 51.5 ± 2.9 Group young: Baseline – 54.2 ± 2.54 16 weeks – 76.2 ± 2.9	***Tigh lean mass (kg)*** Phase 1: Group old: Baseline – 10.72 ± 0.53 16 weeks – 11.16 ± 0.57 Group young: Baseline – 12.43 ± 0.49 16 weeks – 13.13 ± 0.51
Fragala et al. 2014	Community-dwelling; Group 1: *n* = 12 (8/4); (70,8 ± 6.8 y) Group 2: *n* = 11 (5/6); (69.6 ± 5.5 y)	***Hand grip strength (kg)*** Group 1: Baseline – 36.25 ± 10.94 Phase 1 – 39.17 ± 13.58 Phase 2 – 40.08 ± 15.72 Group 2: Baseline – 32.82 ± 14.17 Phase 1 – 34.18 ± 16.48 Phase 2 – 35.55 ± 15.71	***Lean body mass (kg)*** Group 1: Baseline – 47.70 ± 10.67 Phase 1 – 47.92 ± 10.51 Phase 2 – 49.19 ± 10.88 Group 2: Baseline – 49.58 ± 13.48 Phase 1 – 49.51 ± 13.23 Phase 2 – 48.97 ± 12.84
Scanlon et al. 2014	Healthy men & women; Group RT: *n* = 13; (71.1 ± 6.7 y) Group control: *n* = 12; (70.1 ± 5.5 y)	***Knee extensor strength (kg)*** Group RT: Baseline – 39.20 ± 15.90 6 weeks – 51.70 ± 17.60 Group control:	***Tigh lean mass (kg)*** Group RT: Baseline – 5.4 ± 1.3 6 weeks – 5.4 ± 1.3 ***Lean body mass (kg)*** Group RT: Baseline – 47.6 ± 10.6 6 weeks – 47.9 ± 10.5 Group control:

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		Baseline – 31.10 ± 11.80 6 weeks – 33.30 ± 14.70	Group control: Baseline – 5.7 ± 2.2 6 weeks – 5.8 ± 2.4	Baseline – 49.5 ± 13.4 6 weeks – 49.5 ± 13.2
Watanabe et al. 2014	Active older adults but not engaged in regular resistance exercise; Group LST: *n* = 9 (7/2); (69.0 ± 4.7 y) Group CON: *n* = 9 (7/2); (69.9 ± 5.1 y)	NA	***Body mass (kg)*** Baseline: Group LST: 60.8 ± 13.2 Group CON: 58.3 ± 13	

DT, detraining; RT, resistance training; EET, eccentric ergometer training; CT, cognitive training; LST, low-intensity resistance training with slow movement and tonic force generation; CON, low-intensity resistance training with normal speed; NA, not applicable.

Table 3 – Exercise training programs, assessment of variables analysed and main results

Reference	Exercise Training Program	Assessment	Main results
	Description (duration, weeks)		
Mueller et al. 2009	Training period: 12 weeks; 2 guided sessions (45 min)/week RT protocol: Lower limb exercises (leg press, knee extension, leg curl, hip extension) 10 min warm-up; 20 min training; 10 min cool-down (stretching) 3 sets of 10 repetitions EET protocol: Eccentric bike ergometer with initial load very low (30 W ♀, 50 W ♂) for 5 min Training duration was gradually increased in 5 min steps until reach 20 min before imposed load was ramped (ramped in consecutive sessions by 20% of the individual maximal power output) 10 min warm-up in conventional ergometer with minimal loads (10 W ♀, 20 W ♂); 20 min training; 10 min cool-down (stretching) CT consisted of computer-guided cognitive training. Subjects did not perform any physical training and served as control.	Timed up & go and Berg balance scale: Assess risk of falling DEXA (lean and fat tissue mass): Fat and lean values of thigs and legs including right and left extremities Biopsies (Bergström technique): From mid-thigh position of VLM Histochemistry: Myofiber classification Myofiber distribution Maximal isometric extension of the legs Strength test (force platform – 90º angle; ankle-knee-hip) Eccentric coordination Ability to match instantaneous muscle torque to eccentric target load	Maximal isometric leg extension (MEL: +8.4 ± 1.7%) and eccentric coordination (COORD: -43 ± 4%) were significantly improved in EET but not in RT (MEL: -2.3 ± 2.0%; COORD: -13 ± 3%) and CT (MEL: -2.3 ± 2.5%; COORD: -12 ± 5%), respectively. Loss of body fat (-5.0 ± 1.1%) and thigh fat (-6.9% ± 1.5%) in EET subjects only. Relative thigh lean mass increased with EET (+2.5 ± 0.6%) and RT (+2.0 ± 0.3%) and correlated negatively with type IIX/type II muscle fibre ratios. At low frequency resistance or eccentric training was similarly successful in improve muscle functional and structural parameters
Bickel et al.	Two-phase exercise trial of RT:	Muscle biopsy (VLM) for Immunofluorescence	In phase 1 older people gained 4.2% of TLM

2011	Phase 1: progressive RT (16 weeks): Two groups: young (*n* =39) and old (*n* = 31) 35 min/session; 3 days/week; 5 min warm-up on cycle ergometer or treadmill; exercises (knee extension, leg press and squats) 3 sets of 8-12 repetitions (90 sec rest between sets). Phase 2: detraining/ maintenance training (32 weeks)	microscopy (myofibril typing): CSA; Myofibril distribution DEXA: TLM Voluntary strength (1 RM): squat, leg press, knee extension	1RM strength improved in majority during the first 8 weeks. Maintenance of the results (muscle mass) for 8 months (32 weeks) with 1x / week workout. Maintenance among younger but the older ones need a higher frequency
Fragala et al. 2014	Two-phase experimental protocol of RT: 3 sets of 8-15 repetitions of 7 to 8 exercises at moderate intensity (perceived exertion of 5-6 on a 10-point scale) Standardized dynamic warm-up and cool down. ACSM and NSCA guidelines	DEXA (Whole body scan): MQI LBM Hand grip strength: Maximum value	RT significantly and clinically improved MQI (203.4 ± 64.31 to 244.3 ± 82.92W), gait time (1.85 ± 0.36 to 1.66 ± 0.27s) and sit-to-stand performance (13.21 ± 2.51 to 11.05 ± 1.58s). Changes in LBM and hand grip strength were not significant or clinically meaningful.
Scanlon et al. 2014	RT protocol (6 weeks): 2 workouts/week, 48h between sessions for full recovery; 2-4 sets of 8-12 repetitions of 6-10 exercises at sub-maximal intensity (perceived exertion of 5-6 on a 10-point scale); warm-up and cool down. ACSM guidelines	DEXA (total and regional body composition): TLM Ultrasonography (Rectus femoris and Vastus lateralis architecture of dominant leg) CSA MT Fascicle length PANG Echo intensity Physiological CSA Knee extensor strength (maximal voluntary isotonic strength) Muscle quality	RT resulted in significant increases in strength and muscle quality of 32% and 31% respectively. CSA of VLM increased by 7.4% ($p \leq 0.05$). Physiological CSA of the thigh was related significantly to strength ($r = 0.57$; $p \leq 0.05$) and demonstrated a significant interaction after training ($p \leq 0.05$). Change in physiological CSA of VLM was associated with change in strength independent of any other measure. Six weeks of progressive resistance training was sufficient to increase muscle strength, muscle quality (relative strength) and muscle architecture
Watanabe et al. 2014	Training period: 12 weeks, twice a week LST and CON protocols differed only in exercise movement. Both groups repeated their movements at constant speed and frequency with the aid of a metronome LST: 3-s eccentric, 3-s concentric and 1-s isometric actions with no rest between each repetition	EMG signals during exercise Left VLM Blood lactate concentration Measured before and after a single bout of exercise during weeks 8-9 of the intervention period Blood pressure	After 12 weeks training: CSA of the quadriceps muscle increased (5.0%, $p<0.001$) and isometric and isokinetic knee extension strengths ($p<0.05$) in LST group; the strength of the extensors ($p<0.05$) but not CSA increased in CON group; there were no differences in the peak systolic

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	CON: 1-s concentric and 1-s eccentric actions with 1-s rest between each repetition Exercise session: 3 sets of 13 repetitions with a between set rest period of 60 sec Exercise volume (50% 1RM, 8 repetitions × 3 sets)	Measured at left radial artery continuously during exercise in weeks 10-11 Magnetic resonance image Muscle CSA of the right thigh Images obtained before and after the 12-week training period Muscle strength 1RM Isometric and isokinetic strengths were measured using an isokinetic dynamometer (Biodex) before and after the 12-week training period (every 4-weeks)	blood pressure during both protocols.

RT, resistance training; EET, eccentric ergometer training; CT, cognitive training; LST, low-intensity resistance training with slow movement and tonic force generation; CON, low-intensity resistance training with normal speed; MEL, Maximal isometric leg extension; COORD, eccentric coordination; VLM, vastus lateralis muscle; DEXA, dual-energy X-ray absorptiometry; EMG, electromyography; TLM, thigh lean mass; RM, repetition maximum; MQI; muscle quality index; LBM, Lean body mass; ACSM, American College of Sport Medicine; NSCA, National Strength and Conditioning Association; CSA, cross sectional area; MT, muscle thickness; PANG, pennation angle;

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Discussion

Sarcopenia is a growing societal healthcare problem due to rapid expansion of the elderly population and the limited number of therapeutic approaches to this problem [6]. Evidence has shown that older adults, who are less physically active, are more likely to have lower skeletal muscle mass and strength and are at an increased risk of developing sarcopenia [5].

Several studies show that RT increases the functionality of the elderly and that participation earlier in life may provide superior effectiveness in the prevention / treatment of sarcopenia [18]. According ACSM [19], effectiveness and outcomes of such exercise depends on several factors: intensity, training volume, frequency and type of exercises recommended, recovery time between workouts and frequency of training.

In a systematic review in 2013 authors referred that RT should be done two days or more per week, using one set of 8-10 exercises for the whole body and at moderate to vigorous level of effort enabling 8-12 repetitions [2]. The type of exercises recommended includes strengthening of the entire body with progressive strength or RT and other activities involving large muscle groups. The RT in these five studies meets the standard criteria of two or more days per week and more than one set, but some studies referred to perform more than 12 repetitions, because intensity was lower [14,15].

In two studies [13,14], the RT duration was 6 weeks, but the number of repetitions was different ranging between 3 sets of 7-8 exercises with 8-15 repetitions at moderate intensity [13] and 2–4 sets of 6-10 exercises with 8–12 repetitions with an intensity at 85% of 1RM. Despite the difference between them, both RTs showed an increase in the MQI of 18% in group 1 and 31% in group 2. The different results in these may be due to the different intensities of training. Those results are in accordance with ACSM guidelines [19], where high-intensity RT showed better results than low intensity RT training. The study of Mueller et al. [16] used a low intensity for the RT. The same low intensity used by Watanabe et al. (30% 1RM) was maintained during the entire RT program. Both authors referred an increment in maximal isometric extension strength but in the study of Mueller et al. (2009) the increment in strength was significant only in the group performing eccentric exercise. This show the importance of intensity of RT for improvements in strength and confirms also the importance of intensities higher than 40% of 1RM for a significant improvement in muscle strength [20]. While low intensity resistance training is not as effective as higher intensity training, it still shows some benefits, which may be of significant importance to older adults who are not able to perform exercise at higher intensities. In general, all the five studies showed increases in strength between 2% and 25% and in muscle quality between 18% and 31.5%. Thus, it seems that 6 weeks of RT is sufficient to increase muscle strength in elderly and the majority of the strength improvement occurs during the first 8 weeks. This is in accordance with physiological changes since in the first phase of an exercise training program directed for muscle strength, the improvements in muscle strength seems to be primarily due to neuromuscular adaptations [21,22] and only after 6-8 weeks the increments in muscle strength are due to increments in muscle mass.

One systematic review has found that an average of 20.5 weeks of RT has produced a significant main effect equal to a 1.1 kilogram increase in LBM in aging men and women [18] particularly in programs with higher volume of training.

From the analyses of these 5 studies it seems that the duration of 6 weeks of RT was not enough to increase LBM. Only three studies show increments in lean mass and they used duration of 12 weeks of training [15,16] or 16 weeks [12]. This confirms the importance and contribution of duration of RT programs for the increments in strength, showing that only after larger periods of time in training the strength will be due to increments of muscle mass (more contractile mass) and not only to neuromuscular adaptations.

As a limitation in this systematic review we do not exclude the possibility of not identifying all of the relevant studies since the language of all the included studies were only English, Spanish, French and Portuguese due to unfamiliarity of reviewers with other languages. Also we must not forget that a general limitation is that analysis is that do not infer a causal-effect since RT increases in fact increase strength and lean mass which in turn enables an increase in functional capacity of participants also enabling many other behavioural interventions (for example nutritional interventions) that will promote increments in strength and mass and functionality. This should be planned in very old populations or in those whit difficulties in engaging RT programmes.

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Conclusion

Results of current systematic review suggest that RT improves strength and lean mass in older adults which attenuates the development of sarcopenia. However, they should have duration equal or higher than 12 weeks in order to achieve an improvement in muscle mass which could contribute even more for the increments in strength. The increments in strength seems to be achievable in programs of 6 weeks of duration but the intensity should be higher than 30% of 1RM and should be progressively incremented in order to achieve a progressive adaptation.

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