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EFFECTS OF RESISTANCE TRAINING ON MUSCLE STRENGTH IN OLDER ADULTS: SYSTEMATIC REVIEW

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ABSTRACT

The systematic review aims to summarise and synthesise the evidence about the effect of resistance training program (using both machines, elastic band, free weights exercises) on muscle strength in older adults. Major electronic database were searched (Pubmed, Google Scholar, Web of science). Randomized controlled trials (RCTs) and non-randomized interventional studies explored the effects of resistance training in older adults (i.e., 65 of age and older) on muscle strength were included in the review. 4622 studies were identified, and after duplicates were removed, 2219 studies remained. 2195 records were removed due to the abstract not meeting the inclusion criteria. 24 full-text articles were assessed further, and 17 of the articles were identified as meeting the criteria for inclusion. Seventeen studies remained and were included in this review. Resistance training in the elderly (>65 years) increases muscle strength by increasing muscle mass and by improving the recruitment of motor units, and increasing their firing rate. Muscle mass can be increased through training at an intensity corresponding to 60% to 85% of the individual maximum voluntary strength. The present review showed an effect of resistance training on muscle strength. We found that older adults can increase muscle strength by participating in resistance training program. Review suggests that RT has a positive effect on muscle strength in older adults.

Key words: resistance training, strength training, aging, muscle strength, older adults

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INTRODUCTION

In older adults, there is now strong evidence from randomized controlled trials (RCTs) that even in the oldest old, muscle strength can be increased with a strength training program that uses a progressive overload (Latham et al., 2004; Liu & Latham, 2009). Muscular weakness plays a principal role in the pathogenesis of frailty and functional impairment that occurs with aging, and contributes to numerous disease processes. Maximal strength capacity reaches a peak sometime around the second or third decade of life, and by the fifth decade, begins a gradual decline (Larsson et al., 1979; Vandervoort & McComas, 1986; Narici et al., 1991; Lindle et al., 1997; Metter et al., 1997). This deterioration, which is typically attributed to diminished levels of activity or disuse/immobilization due to disease, has been documented primarily through cross-sectional research, and appears to increase in severity after the age of 65 (Baumgartner et al., 1998).

Strength training in the older adult, besides increasing overall strength, has been shown to have positive effects on improving bone density, energy metabolism, insulin action and functional status. Specifically, studies have now shown that targeted exercise referred to as strength training (also known as weight lifting or progressive resistance training) has the power to combat weakness and frailty and their debilitating consequences (Roubenoff & Hughes, 2000) Functionally, strength training is an activity in which muscles move dynamically against weight (or other resistance) with small but consistent increases in the amount of weight being lifted over time.

Strength increases for older adults have been documented for resistance-training intensities ranging from 50–100% of 1RM (repetition maximum) (Fiatarone et al., 1990; Hunter & Treuth, 1995; Vincent et al., 2002), performed for 1–3 sets per exercise (Hunter & Treuth, 1995; Adams et al., 2001), at a frequency of 1–3 times per week (Taaffee et al., 1999; Hunter et al., 2001) on machines and free weights (Fiatarone et al., 1990; Adams et al., 2001; Vincent et al., 2002), with protocol durations of 8 weeks to 1 year (Fiatarone et al., 1990; Frontera et al., 1991; Pyka et al., 1994; Brandon et al., 1997; Taaffe et al., 1999; Brandon et al., 2000; Westhoof et al., 2000). Within this robustly effective range of resistance-training stimulus, there is likely some optimal combination of resistance-training program variables that will elicit maximal strength gains in older adults. Additional studies specific to older adults are needed to better define the effect of manipulating key program variables (e.g., intensity) on outcomes (Pyka et al., 1994; Tan, 1994; Fleck, 1999, 2002; Fleck & Kraemer, 2003). Therefore, resistance training must be a key component to be introduced in training programs for the elderly since, in addition to the benefits mentioned, it may produce neuromuscular improvements such as increased muscle mass, strength, and functional capacity (Lopez et al., 2018).

Therefore, this paper aimed to perform a systematic review of randomized controlled trials within an aging population to investigate the effect of resistance training on muscle strength in elderly adults.

MATERIAL AND METHODS

Three electronic databases (PubMed, Web of Science and Google Scholar) were searched for randomized controlled trials that measured at least one key outcome measure focusing on strength in older adults. Search terms used included: resistance training, or strength training or weight training, muscle strength. The search was further limited to "clinical trials", in "humans", published in "the last sixteen (16) years" (January 2002 to December 2018), "adult: 65+ years" of age, and published in "English".

Study Selection—Inclusion Criteria

The inclusion criteria for this systematic review were full-length research articles published in peer-reviewed academic journals in the English language. Analysis was confined to studies published in English-language peer-reviewed journals that met the following criteria: (a) an experimental trial involving resistance training both low-load training (≤60% 1RM) and high-load training (>60% 1RM); (b) using machines, free weight exercise, or elastic bands; (c) at least one method of estimating changes in muscle mass or dynamic, isometric, or isokinetic strength was used; (d) the training protocol lasted for a minimum of 6 weeks; (e) the study involved participants with a median age of 60+ years. Seventeen studies met the inclusion criteria and were included in this systematic review.

Study Selection—Exclusion Criteria

Abstracts, conference presentations, poster presentations, books or book chapters, unpublished papers, proposed protocols, or retrospective designs were excluded. Studies were also excluded if the participants were taking supplements, or if the average age of participants was ≤60 years.

RESULTS

The initial search resulted in 4622 studies; after duplicates were removed, 2219 studies remained, and the abstracts were reviewed for meeting the inclusion criteria. Following the initial screening process, 2195 records were removed due to the abstract not meeting the inclusion criteria. 24 full-text articles were assessed further and 17 of the articles were identified as meeting the criteria for inclusion. 17 studies remained, and all were included in the systematic review.

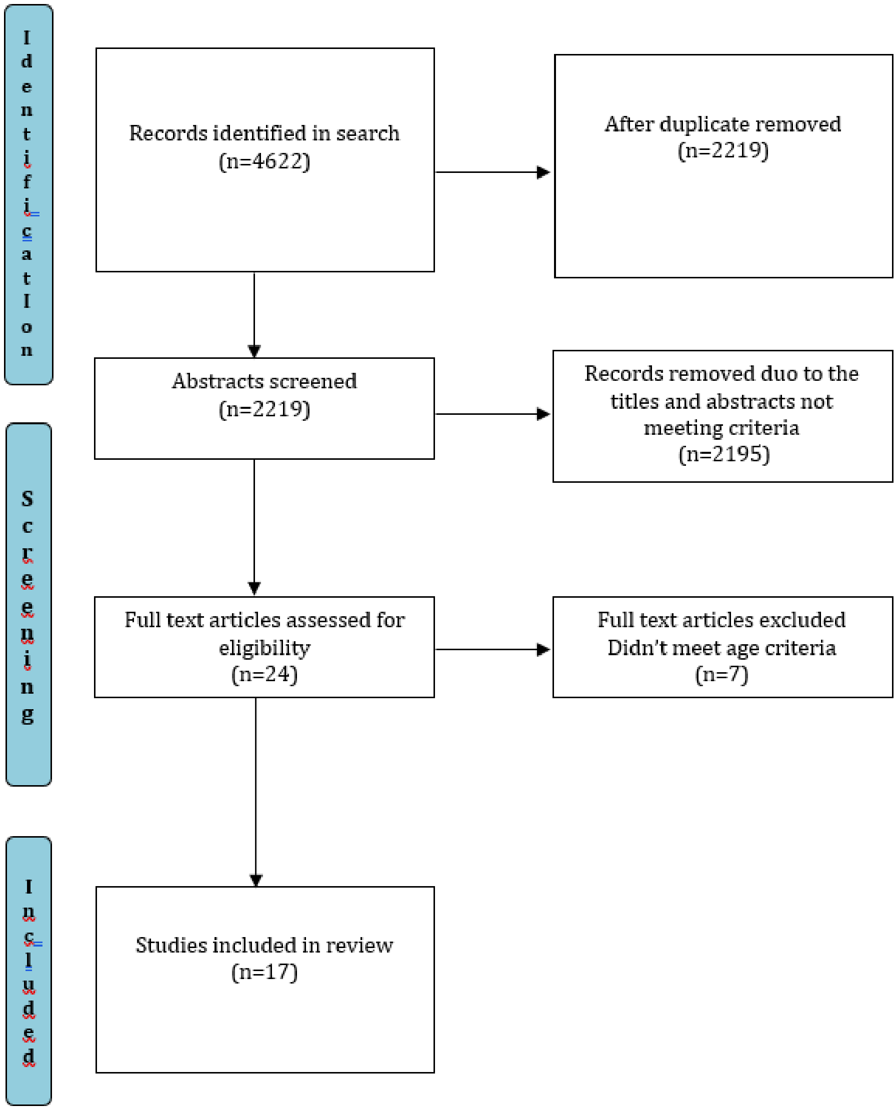

Figure 1. Article selection flow-chart

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Table 1. Resistance training intervention details in older adults

Authors	Type of exercise	Days/ week	Weeks	Sets	Reps	Rest interval	Load
Gonzales et al. (2014)	Bodyweight/ machines	2	6	3	8-15	NR	progressive
Marques et al. (2011)	Machines	3	32	3	6-8	>2min	75-85% 1RM
Nicklas et al. (2015)	Machines	3	20	3	10	1min	70% 1RM
Yanagita (2018)	Machines	2	10	3	8-12	NR	60-70% 1RM
Castaneda et al. (2002)	Resistance/ free weights	3	16	3	8	NR	70-80% 1RM
Dunstan et al. (2002)	Resistance training	3	24	3	8-10	NR	75-85% 1RM
Chad Harris et al. (2004)	Machines	2	18	2-4	15-9-6	2-3min	67-84% 1RM
Evelien Van Roie et al. (2013)	Machines	3	12	1-2	10-15	1min	80% 1RM
Donoghue et al. (2006)	Machines	1-2	9	1	10-15	NR	75% 1RM
Hanson et al. (2009)	Machines	3	22	4-5	5	30-180sec	50% 1RM
Katula et al. (2006)	Machines	3	6	2	8-12	NR	70-80% 1RM
Kenis et al. (2013)	Resistance and aerobic	3	48	1-2	8-15	NR	75-85% 1RM

Table 1. Continued

Authors	Type of exercise	Days/ week	Weeks	Sets	Reps	Rest interval	Load
Sundstrup et al. (2016)	HST	2	16	3	10	1.5min	75% 1RM
Lopez et al. (2018)	HST	3	12	3	8	1min	60% 1RM
Lopes et al. (2016)	HST	3	12	2.5	7	NR	80% 1RM
Bento & Rodacki, (2015)	HST	3	12	2.5	10	2	77.5% 1RM
Caserotti et al. (2008)	HST	2	12	4	9	NR	77.5% 1RM

Legend: NR = not reported, progressive = article only stated progressive resistance training when referring to the load applied, 1RM = 1 repetition maximum, CR10 = Borg rating of perceived exertion CR10, MTL = maximum tolerated load, HST = heavy strength training.

Resistance training intervention duration ranged greatly from 6 to 48 weeks, two studies reporting data for 6 weeks (Katula et al., 2006; Gonzales et al., 2014), one study reporting for 9 weeks (Dongue et al., 2006), five studies reporting for 12 weeks (Caseratti et al., 2008; Van Roie et al., 2013; Lopes et al., 2016; Bento & Rodacki, 2015; Lopez et al., 2018), one study reporting 10 weeks (Yanagita, 2018), two studies reporting 16 weeks (Castaneda et al., 2002; Sunastrup et al., 2016), one study reporting for 18 weeks (Chad Harris et al., 2004), one study reporting 20 weeks (Nicklas et al., 2015), one study reporting 22 weeks (Hanson et al., 2009), one study reporting 24 weeks (Dunstan et al., 2002), one study reporting 32 weeks (Marques et al., 2011), one study reporting 48 weeks (Kenis et al., 2013).

All seventeen studies described the frequency of training in "days/week"; six studies conducting the intervention 2 days/week (Chad Harris et al., 2004; Donghue et al., 2006; Gonzales et al., 2014; Sundstrup et al., 2016; Yanagita, 2018), and eleven studies conducting the interventions 3 days/week (Castaned et al., 2002; Dunstan et al., 2002; Katula et al., 2006; Hanson et al., 2009; Van Roie et al., 2013; Kenise et al., 2013; Marques et al., 2014; Niclas et al., 2015; Bento & Rodri, 2015; Lopes et al., 2016; Lopez et al., 2018).

Regarding the number of sets and repetitions used in the RT interventions, the research appears to be relatively diverse. The number of sets used in the interventions included one intervention using 1 set (Donghue et al., 2006), two interventions using 2 sets (Katula et al., 2006; Marques et al., 2011), eight interventions using 3 sets (Castaneda et al., 2002; Dunstan et al., 2002; Gonzales et al., 2014; Niklas et al., 2015; Lopes et al., 2016; Sundstrup et al., 2016; Lopez et al., 2018; Yanagita, 2018), one study using 4 sets (Caserotti et al., 2008), four studies simply using a “varied” use of sets (Harris et al., 2004; Hanson et al., 2009; Van Roie et al., 2013; Kenis et al., 2013). The number of repetitions used per set of exercise in the respective interventions included: one study using 5 (Hanson et al., 2009), one study using 7 (Lopes et al., 2016), two studies using 8 (Castaneda et al., 2002; Lopez et al., 2018), one study using 9 (Caserotti et al., 2008), three studies using 10 (Niklas et al., 2015; Bento & Rodri, 2015; Sundstrup et al., 2016), two studies using 8 to 12 (Katula et al., 2006; Yanagita, 2018), two studies using 8 to 15 (Kenis et al., 2013; Gonzales et al., 2014), two studies using 10 to 15 (Donghue et al., 2006; Van Roie et al., 2013), one study only using 10 (Nicklas et al., 2015), one study using a fixed 15, 9, and 6 repetitions model (Harri et al., 2004).

All studies reported the type of resistance modalities used during the training sessions. Of which, seven studies reported using resistance machines (Donghue et al., 2006; Katula et al., 2006; Hanson et al., 2009; Marques et al., 2011; Van Roie et al., 2013; Nicklas et al., 2015; Yanagita, 2018), eight studies utilizing free weights (Castaneda et al., 2002; Dunstan et al., 2002; Caserotti et al., 2008; Kenis et al., 2013; Bento & Rodacki, 2015; Lopes et al., 2016; Sundstrup et al., 2016; Lopez et al., 2018), one study utilizing both free weights and machines (Gonzales et al., 2014), one study utilizing resistance and aerobic (Kenis et al., 2013).

Study Characteristics

Seventeen studies were included in the review, and all were published in the English language. The randomized controlled trials were conducted in the following countries:

USA = 5, Belgium = 2, Brazil = 2, Denmark = 1 Portugal =1, Japan = 1, Iceland = 1, and Switzerland = 1. The total number of participants analyzed in all studies was 934 (including male and female participants).

Eleven of the twelve studies had reported the gender of the participants and approximately 60% of them were female (149 males to 304 females). One study reported mean ages of ≥60–65 years (Van Roie et al., 2013), four studies reported mean ages between 71–81 years (Harris et al., 2004; Donghue et al., 2006; Nicklas et al., 2013; Gonzales et al., 2014), and five study reporting a mean ages between 71-82 years (Castaned et al., 2002; Dusntan et al., 2002; Katula et al., 2006; Hasnon et al., 2009; Gonzales et al., 2014), seven studies reported mean ages between 65–71 years (Marques et al., 2011; Kenis et al., 2013; Bento & Rodri, 2015; Lopes et al., 2016; Sundsttrup et al., 2016; Lopez et al., 2018; Yanagita, 2018).

DISCUSSION

This review found that strength training is beneficial to older people. Older adults in the strength training group had significant improvements in strength and function and reductions in pains. All of these outcomes had a moderate effect size.

Clark and Manini (2010) found that very elderly individuals can increase muscle size despite their advancing age, although the expected improvements may be small to modest (ES = 0.30; 95% CI 0.10, 0.50). Nonetheless, the finding that the very elderly can increase their muscle size is highly relevant, given that sarcopenia may increase the risk of falls and fractures, increase frailty, decrease functional independence and quality of life as well as increase the risk of chronic disease and all-cause mortality (Clark & Manini, 2010). There are estimates that in the very elderly, muscle size is reduced at a rate of 0.64–0.98% per year (ES 0.14–0.23) (Delmonico et al., 2009; Mitchell et al., 2010). Delmonico and colleagues (2009) in their study suggest that resistance training interventions lasting from 10 to 18 weeks with a training frequency of 2–3 days per week can increase muscle size that was potentially lost over multiple years of aging. This finding is of public great health importance, if we consider estimates that the prevalence of sarcopenia in adults older than 75 years ranges from 27 to 60% (Baumgartner et al., 1998).

Studies assessing the influence of resistance-training intensity on strength gain in older adults are limited. Further, it is difficult to make direct comparisons with other studies, as the potential combinations of the acute program variables make comparisons difficult. In regard to the effects of intensity on strength gain, the present study failed to support the data of Hunter and Treuth (1995). In their study, 60–77-year-old sedentary women trained 3 times per week for 16 weeks, with subjects performing 2 sets of 12 repetitions on 10 machine exercises at intensities ranging between 50% and 80% of 1RM. When comparing the percentage RM used during the last 2 weeks of the study, the authors found that subjects who trained at a lower intensity (50–60% of 1RM) increased strength more than those training at a higher intensity (70–80% of 1RM). Vincent et al. (2002) controlled training volume between 2 groups of older adults (60–83 years) who trained at either 50% of 1RM for 1 set of 13 repetitions or 80% of 1RM for 1 set of 8 repetitions, 3 times a week for 24 weeks. The common finding in these studies is that, in untrained older adults, both low- and high-intensity machine-based resistance-training programs are effective at increasing maximum strength in studies lasting 6 months or less. However, large differences in the levels of strength increase occurred between the two studies. Vincent and colleagues reported an increase in 1RM strength of just over 17% for both groups over the 6-month training program. Subjects in the current study increased 1RM strength between 44 and 51% in 18 weeks of training. Variance in training volume could explain the differences in strength increases between the two studies. The volume for the current study was over 50% greater than that employed by Vincent et al. (2002), as multiple sets were employed in our investigation, while a single-set paradigm was used by the other researchers. Sundstrup et al. (2016) in their study concluded, both football and strength training led to increased hamstring muscle strength, however, the time-course of adaptation appeared to differ between the two exercise modalities. While ST led to early significant improvements (0–4 months) in hamstring muscle strength development, a longer period (12 months) was needed to achieve positive adaptations in hamstring strength with FT. Van Roie et al. (2013) in their study investigated whether high-repetition low-resistance exercise protocols (LOW and LOW+) would be similarly effective in achieving gains in muscle volume, muscle strength, force-velocity characteristics, and functional performance as traditional high resistance training (HIGH). In their study authors concluded that despite doing a smaller volume of work compared to LOW, HIGH and LOW+ achieved the same or greater improvements on muscle volume, muscle strength, and functional performance. In particular, all groups demonstrated similar gains in muscle volume (2.4 - 3.2%), irrespective of the resistance used during training. These results are in line with previous research showing that low-resistance exercise, as long as maximal effort is reached, can induce comparable hypertrophic responses as high-resistance exercise (Taaffe et al., 1996; Takarada et al., 2000; Mitchell et al., 2012).

CONCLUSION

Regular strength training can improve muscle function, increase bone strength, improve balance and coordination, and have a meaningful effect on the ability of older adults to maintain a high-quality lifestyle. This systematic review found that the very elderly can increase their muscle strength and size by participating in resistance training programs. Moreover, resistance training was found to be an effective way to improve muscle strength even among the oldest-old. Although the principles of strength training are similar for individuals of all ages and abilities, unique factors specific to older adults must be considered when designing strength training programs. Perhaps the best recommendation for older adults who want to optimize their current and future health is to begin a sensible strength training program that is consistent with their current needs, abilities, and medical history. Research shows that resistance training can be a safe and effective method of conditioning for older adults both males and females. The potential benefits are multifactorial, including positive effects on a variety of physical performance variables (e.g., strength and power), health markers (e.g., body composition and cardiac function), and psychosocial development (e.g., self-image and confidence). It is clear that men and women of all ages retain the capacity to adapt to strength training. Because muscle and bone weakness is a common characteristic of advancing age, older adults can benefit from physical activity programs that preserve or enhance muscular fitness and bone strength. More research is needed on the effects of resistance training on handgrip strength and muscle fiber hypertrophy.

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