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Review

Effect of resistance training on muscle strength and rate of force development in healthy older adults: A systematic review and meta-analysis

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ABSTRACT

Rapid force capacity, identified by rate of rise in contractile force at the onset of contraction, i.e., the rate of force development (RFD), has been considered an important neuromuscular parameter of physical fitness in elderly individuals. Randomized control studies conducted in adults have found that resistance training may elicit different outcomes in terms of RFD and muscle strength. Thus, the main purpose of this study was to review systematically the literature for studies regarding the influence of resistance training on muscle strength and RFD in elderly persons. A literature search was performed in major electronic databases from inception to March 2017. Studies including health individuals with a mean age ≥ 60 years, describing the effect of resistance training on RFD and muscle strength were found eligible. The outcomes were calculated as the difference in percentage change between control and experimental groups (% change) and data were presented as mean ± 95% confidence limits. Meta-analyses were performed using a random-effects model and, in addition, simple and multiple meta-regression analyses were used to identify effects of age, training type, sessions per week and training duration on % change in RFD and muscle strength. Thirteen training effects were collected from 10 studies included in the meta-analysis. The resistance training program had a moderate beneficial effect on both muscle strength (% change = 18.40%, 95% CL 13.69 – 23.30, $p < 0.001$) and RFD (% change = 26.68, 95% CL 14.41–35.52, $p < 0.001$). Results of the meta-regression revealed that the variables age, training type (i.e., strength and explosive), training duration (4–16 weeks) and sessions per week had no significant effects on muscle strength and RFD improvement. Moreover, there was no significant relationship ($p = 0.073$) between the changes in muscle strength and RFD. It can be concluded that explosive training and heavy strength training are effective resistance training methods aiming to improve both muscle strength and RFD after short-to-medium training period. However, muscle strength and RFD seem to adapt differently to resistance training programs, suggesting caution for their interchangeable use in clinical assessments of the elderly.

1. Introduction

Aging is associated with decrease in muscle strength, which has been explained by factors such as neural changes (i.e., reduced voluntary muscle activation) (Manini and Clark, 2012) and sarcopenia (i.e., losses in muscle size and function) (Häkkinen et al., 1998; Reeves et al., 2004). Thus, resistance training has been frequently included in the exercise programs aiming to improve muscle function and to maintain independence in the later life. Indeed, some systematic reviews and meta-analyses have shown that resistance training can increase muscle strength, even in very old individuals (Silva et al., 2014; Borde et al., 2015; Straight et al., 2016). However, the increased muscle strength in elderly seems to exert only a small to moderate effect on performance during daily activities such as stair climbing, chair rising and walking (Latham et al., 2004; Liu and Latham, 2009). Thus, other neuromuscular parameters related to muscle function must be investigated aiming to elaborate a more efficient training program for this population.

Rapid force capacity, identified by rate of rise in contractile force at the onset of contraction, i.e., the rate of force development (RFD), has been considered an important neuromuscular parameter during “explosive” muscle actions (e.g. jumping and sprint running) (Maffiuletti et al., 2016). Since the time window (50–250 ms) involved in the “explosive” movements are very short, they may not allow maximal muscle

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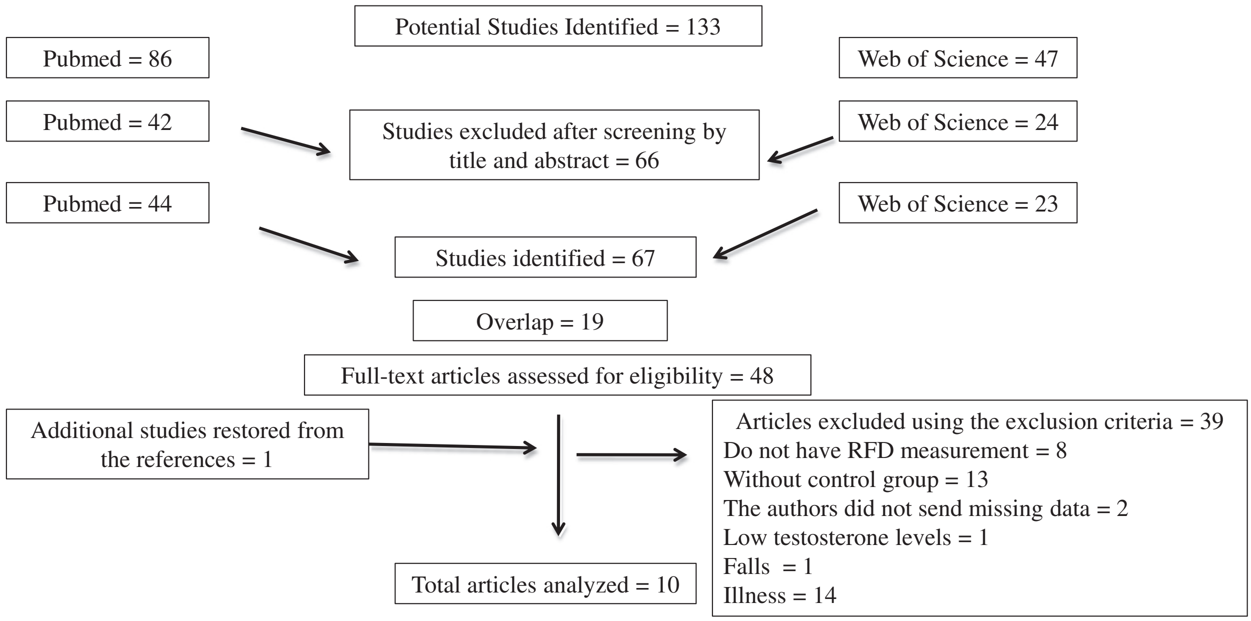

Fig. 1. Flowchart expressing the different phases of the search and selection of the studies included in the meta-analysis.

force to be reached (Aagaard et al., 2010). In addition to the contribution for performance of some sports movements, the RFD has been also considered an important aspect of physical fitness of elderly individuals, since the capacity to rapidly generate force can help during activities of daily living (Aagaard et al., 2010), for balance control (Hess et al., 2006), and to reduce the incidence of falls (Rubenstein, 2006). Although some factors that modulate the strength responses to training are well known in healthy older adults (Silva et al., 2014), much less is known about how specific exercise interventions improve RFD in this population. It is important to note that the resistance training in adults may elicit different outcomes in terms of RFD obtained during the early phase of muscle contraction (i.e., < 100 ms) and muscle strength (Oliveira et al., 2013; de Oliveira et al., 2013). Indeed, the mechanisms associated with the RFD early (neural drive, contractile properties and fiber type composition) and RFD late (muscle size, muscle strength, neural drive and the stiffness of the tendon-aponeurosis complex) are not the same (Andersen and Aagaard, 2006). Thus, it can be interesting to analyze, in the same healthy old adults, if muscle strength and RFD early respond in a similar manner to the different resistance training programs. In addition to the theoretical implications, this analysis can have important practical application regarding the neuromuscular evaluation and training prescription, since the logistical and resource constraints (i.e., equipment) can limit the widespread determination of RFD as a pragmatic measurement.

Thus, the main purpose of this study was to review systematically the literature for studies regarding the influence of resistance training on muscle strength and RFD in elderly persons. Furthermore, the present meta-analysis, using meta-regression, examines how specific resistance training variables affect muscle strength and RFD. We hypothesized that resistance training can promote different effects on measures of muscle strength and RFD in healthy old adults.

2. Material and methods

2.1. Literature search

We performed a computerized systematic literature search up to March 2017, for Pubmed and Web of Science databases, including all peer-reviewed longitudinal studies that analyzed the effects of resistance training on the muscle strength and RFD. The following Boolean search strategy was applied using the operators 'and' and 'or': 'elderly', 'aged', 'aging', 'rate of torque development', rate of force development', 'strength development rate', 'weight training', 'resistance training', 'weight bearing exercise program' and 'strength training'. Reference lists of the included articles were checked in an effort to identify suitable studies inclusion in the database. Attempts were also made to contact the authors of the selected articles to request any missing relevant information. This systematic review and meta-analysis is reported in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement (Moher et al., 2009).

2.2. Inclusion and exclusion criteria

Resistance training was characterized as exercises where the subject exerted an effort against an external resistance. Studies meeting the following inclusion criteria were considered for review: 1) Available in English; 2) Randomized control studies; 3) Studies that included a test to determine maximal strength and RFD pre- and post-training, and 4) Individuals aged ≥ 60 years (mean age). The exclusion criteria were used in the selected studies: 1) Review; 2) Illness; 3) Participants with low testosterone levels; 4) Falls; 5) Did not send the data after e-mail contact.

2.3. Coding of studies

A search of electronic databases and a scan of article reference list revealed 133 potential studies (Fig. 1). Based on a review of the title or abstract, 66 articles were excluded. Sixty-seven studies were identified. Nineteen studies were excluded by duplicate. Forty-eight studies were assessed for eligibility. One study was restored from the references. Thirty-nine studies were excluded using the exclusion criteria. Ten full-text articles were included for the meta-analysis.

The outcome measurements were muscle strength and RFD. In all studies, both muscle strength and RFD were measured during isometric contraction, performed in the knee extensors (nine studies) and plantar flexors (one study). If RFD was measured at different times from the onset of contraction, only the highest value was considered for analysis. When a study yielded multiple weight training programs, multiple effects (i.e., heavy strength training and explosive training) were calculated and included separately. The training programs were classified as: 1) Heavy strength training: exercises using ≤ 10 repetitions and/or