Brief review
Muscle power training in the institutionalized frail: a new approach to counteracting functional declines and very late-life disability

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Abstract
Skeletal muscle power decreases earlier than muscle strength with advancing age and is more strongly associated with functional test performance than muscle strength in elderly populations. In addition, some studies have shown that resistance training designed to improve muscle power output (high speed of movement) enhances several functional outcomes in the healthy elderly. Therefore, muscle power has emerged as a factor that is also potentially associated with functional limitations in frail elderly adults. The purpose of this review was to provide recent evidence regarding the association between skeletal muscle power and functional capacity in physically frail individuals. Scielo, Science Citation Index, MEDLINE, Scopus, Sport Discus and ScienceDirect databases were searched from 1990 to 2014. Recently, it has been shown that functional capacity among frail elderly adults could be improved by performing resistance training at a high speed of movement with a loading stimulus that optimizes muscle power output. Routine multicomponent interventions that include muscle power training should be prescribed to institutionalized oldest old because such interventions improve the overall physical status of frail elderly individuals and prevent disability and other adverse outcomes. This result is especially important in frail subjects, who urgently need to improve their functional capacities to prevent adverse outcomes such as falls, hospitalizations, disability, or even death.

Introduction: why is skeletal muscle power output important among frail elderly adults?
Frailty has been defined as an age-associated medical syndrome with multiple causes and contributors that is characterized by diminished strength and endurance, and reduced physiologic function that increases an individual’s vulnerability for developing increased dependency and/or death. This syndrome is strongly associated with low muscle mass and puts older individuals at special risk for disability, hospitalization, and death due to falls and many other causes when exposed to a stressor. As a consequence of impaired muscle function, the diagnosis of frailty involves physical impairments, such as low gait speed, fatigue, and low grip strength.

Earliest studies investigating healthy non-institutionalized elderly have shown marked neuromuscular gains in elderly performing explosive-type exercises during a strength training intervention. In fact, it is well known that muscle strength decline is one of the main factors related to poor functional capacity in the oldest old. In addition, muscle power and muscle explosiveness (i.e., the rate at which force can be applied), besides being primary factors for improving performance in most sports, may also be important in extremely old and frail individuals. Indeed, a decreased capacity for high-velocity movements and delayed responsiveness to accidental falls in the lower and upper limbs have
been associated with disability and are a significant cause of injury\textsuperscript{14}. Figure 1 shows the main physiological and phenotypical causes of decline in muscle power output, which in turn increases the risk of loss of independence and disability.

Recently, a strong association has been shown between muscle power output and functional outcomes in the frail institutionalized oldest old\textsuperscript{15}. There is, therefore, a potential role for a focus on muscle power in high-speed power training in enhancing the effects of exercise therapies in elderly frail institutionalized individuals\textsuperscript{14–16}. The aim of this review is to discuss recent evidence regarding the association between skeletal muscle power and functional capacity in institutionalized frail individuals. Overall, we provided a succinct state of art of the strength deficits observed in many older patients and the benefits of strength training in this population. It seems that evidence is beginning to exist about the benefits of explosive (high-velocity) strength training to counteract the functional declines in very late life disability.

**Methods: literature search**

**Search strategy**

The Scielo, Science Citation Index, MEDLINE, Scopus, Sport Discus and ScienceDirect databases were searched from November 2012 to February 2014 for published articles based on original scientific investigations during the period from 1990 to 2014. The search terms included various combinations of the following keywords: 'strength training in frail', 'exercise training in elderly', 'multicomponent exercise interventions', 'muscle power in elderly', 'muscle strength in elderly', 'mobility-limited elderly'. The names of authors who were cited in some of the studies were also utilized in the searches.

**Criteria for study consideration**

The search criteria were as follows: (i) the studies must have been published in English, peer-reviewed, scholarly journals; (ii) dissertations, theses and conference proceedings were excluded; (iii) the studies must have mentioned the effects of power training programs on muscle strength, muscle power and functional outcomes in the frail elderly or elderly with severe functional decline. The control group must be no physical activity group (maintenance of the habitual lifestyle) or home-based low level recreational exercise intervention with only stretching and relaxation exercises.

**Inclusion of studies**

From the preliminary search, 189 manuscripts had their title read and 22 were selected for a second analysis, which included reading of the abstracts. Six original studies that investigated the effects of strength training
including muscle power exercises in physically frail elderly had their results described in this review. Additionally, original studies and systematic reviews on the effects of different exercise interventions in the frail elderly, as well as on the effects of power training in the healthy elderly were included in the discussion.

**What type of exercise intervention approaches should be performed to impact age-related functional declines?**

Poor health, disability, and dependency do not need to be the inevitable consequences of aging. Indeed, older adults who practice healthy lifestyles, avoid being sedentary, participate in physical exercise (e.g., walking, strength training, or self-adjusted physical activity), use clinical preventive services, and continue to engage with family and friends are more likely to remain healthy, live independently, and incur fewer health-related costs. Due to the physical domains related to frailty, physical activity is one of the most important components in the prevention and treatment of frailty. Indeed, the benefits of physical exercise in improving the functional capacity of frail, older adults have been the focus of considerable recent research.

In a recent systematic review investigating the effectiveness of different exercise interventions on the incidence of falls, gait ability, balance, and strength, 70% of the studies that were included reported a reduction in the incidence of falls, 54% reported enhancements in gait ability, 80% reported improvements in balance, and 70% reported increases in muscle strength. Such interventions, which include resistance training, balance training, endurance training, coordination training, multicomponent exercises (i.e., simultaneous strength, endurance, and balance training), and tai chi, have yielded beneficial effects on certain functional parameters in both frail, elderly subjects living in the community and those living in nursing homes. However, multicomponent exercise programs that include resistance training appear to result in greater overall enhancements given that this type of intervention stimulates several components of physical health, e.g., strength, cardiorespiratory fitness, and balance.

The positive effects of exercise on functional capacity may be observed more often when multiple physical conditioning components (i.e., strength, endurance, or balance) are included in the exercise intervention compared to only one type of exercise. The absence of changes in functional or strength outcomes measured in certain previous studies indicates that the exercise prescription must be carefully adapted to provide a sufficient stimulus for improving not only maximal strength but also the functional capacity and muscle power output.

**What would be the impact of adding muscle power training to exercise routines among the frail elderly?**

Skeletal muscle power decreases earlier than muscle strength with advancing age and is more strongly associated with functional test performance than muscle strength in the elderly populations. In addition, skeletal muscle power has been highlighted as important for the completion of activities of daily living (ADLs), e.g., rising from a chair, walking, and climbing stairs, and increasing skeletal muscle power has been associated with a reduction in the incidence of falls. Furthermore, several previous studies have observed positive training-induced muscle power enhancement in ambulatory, community-dwelling older adults with or without self-reported limitations in physical functioning. Based on these results, it was suggested that functional capacity among frail elderly adults could be improved by performing resistance training at a high speed of movement with a loading stimulus that optimizes muscle power output. Recently, it has been reported that 12 weeks of multicomponent exercise training including explosive resistance training improved muscle power output, strength, muscle cross-sectional area and muscle fat infiltration, as well as functional outcomes and dual task performance in frail institutionalized nonagenarians. Interestingly, in another recent study, it has been shown that 4 weeks of high-speed resistance training combined with walking, cognitive and balance exercises improved the gait ability, balance, and muscle strength, as well as reduced the incidence of falls in frail patients with dementia after long-term physical restraint used in their nursing care.

These novel results are especially relevant because they demonstrate that exercise intervention including muscle power training may bring benefits even in frail patients with cognitive impairment in very poor physical condition. It should be mentioned that, overall, these benefits were achieved only after the inclusion of resistance training in the exercise intervention, because the walking, cognitive and balance exercises performed 4 weeks previous to the resistance training inclusion only improved the balance performance. Thus, routine multicomponent interventions that include muscle power training should be...
prescribed to the institutionalized oldest old because such interventions improve the overall physical status of frail elderly individuals and prevent disability and other adverse outcomes. This result is especially important in frail subjects, who urgently need to improve their functional capacities to prevent adverse outcomes such as falls, hospitalizations, disability, or even death. Additionally, it should be highlighted that resistance exercise not only helps to reduce the risk and incidence of falls in seniors, but may also help to prevent injuries when these falls occur. Table 1 summarizes the methods applied and the results obtained in the studies that have investigated exercise interventions including explosive resistance training in elderly individuals with impaired lower extremity functioning, mobility-limited community-dwelling older adults, community-dwelling pre-frail individuals, institutionalized frail nonagenarians, and frail patients with dementia after long-term physical restraint.

To be efficient, how should a resistance training approach be prescribed?

Resistance training programs that have investigated the adaptations induced by resistance training among frail elderly individuals suggest that performing such routines three times per week, with three sets of 8 to 12 repetitions and an intensity beginning at 20–30% and progressing to 80% of one repetition maximum (1RM), may be well tolerated by frail subjects and result in positive effects on gait and muscle strength. To optimize functional capacity, resistance training programs should include exercises in which the participant’s body weight is used for resistance and in which activities of daily living are simulated (e.g., the ‘sit to stand’ exercise). In addition, balance training should be highlighted that resistance exercise not only helps to reduce the risk and incidence of falls in seniors, but may also help to prevent injuries when these falls occur. Table 1 summarizes the methods applied and the results obtained in the studies that have investigated exercise interventions including explosive resistance training in elderly individuals with impaired lower extremity functioning, mobility-limited community-dwelling older adults, community-dwelling pre-frail individuals, institutionalized frail nonagenarians, and frail patients with dementia after long-term physical restraint.

**Table 1.** Effects of strength training including muscle power exercises in functional and physical outcomes in frail, pre-frail or mobility-limited older individuals.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Age and characteristics</th>
<th>Intervention</th>
<th>Primary results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Katula et al.</td>
<td>Participants with impaired lower extremity functioning (77 ± 7 years)</td>
<td>HVRT or traditional RT 3/wk, 12 wk</td>
<td>▲ Self-efficacy in both training groups;</td>
</tr>
<tr>
<td>Marsh et al.</td>
<td>Participants with impaired lower extremity functioning (77 ± 7 years)</td>
<td>HVRT or traditional RT 3/wk, 12 wk</td>
<td>▲ Satisfaction with physical function only in HVRT group;</td>
</tr>
<tr>
<td>Bean et al.</td>
<td>Mobility-limited community-dwelling participants (75 ± 7 years)</td>
<td>PT that emphasizes task specificity vs. traditional RT 3/wk, 16 wk</td>
<td>▲ Strength outcomes in both groups (20%);</td>
</tr>
<tr>
<td>Zech et al.</td>
<td>Community-dwelling pre-frail individuals (77 ± 7 years)</td>
<td>MCEP including HVRT or traditional RT 2/wk, 12 wk</td>
<td>▲ Muscle power only in the PT group (10%);</td>
</tr>
<tr>
<td>Cadore et al.</td>
<td>Institutionalized frail participants (93 ± 3 years)</td>
<td>MCEP: HVRT + BT, 2/wk, 12 wk</td>
<td>▲ SPPB in both groups.</td>
</tr>
<tr>
<td>Cadore et al.</td>
<td>Frail patients with dementia after long-term physical restraint (88.1 ± 5.1 years)</td>
<td>MCEP: 4 weeks of WT, BT and CE + 4 weeks of WT, BT, CE + HVRT 2/wk, total 8 wk</td>
<td>▲ Greater residual effects after 36 weeks of the training cessation in the HVRT group.</td>
</tr>
</tbody>
</table>

RT, resistance training; HVRT, high-velocity resistance training; PT, power training; BT, balance training; WT, walking training; CE, cognitive exercises; SPPB, Short Physical Performance Battery; MCEP, multicomponent exercise program; TUG, time-up-and-go test; wk, weeks; ↑, increase; ↓, reduction.
muscle power training in frail elderly population should also be further explored. The above-mentioned recommendations expand the recommendations previously published in which multicomponent exercise intervention including strength training seems to result in greater overall physical improvement. Given the data on exercise training interventions in the elderly, certain practical issues may be transferred to general clinical practice. As life expectancy increases, it is crucial that physical training be optimized with the goal of reducing losses in muscle strength and mass. Such training will also serve to reduce the number of falls and improve balance and gait ability among the frail elderly.

Conclusions

Based on the current evidence, a multicomponent exercise intervention program that includes strength, endurance, and balance training appears to be the most effective strategy for improving gait, balance, and strength as well as reducing the rate of falls in elderly individuals. Together, these programs will help to maintain functional capacity during aging. Furthermore, because muscle power is an important predictor of functional capacity, strategies to develop skeletal muscle power in this population must be included to prevent or postpone functional limitations and subsequent disability. Although the effects of exercise interventions on functional outcomes in the frail elderly have been demonstrated, questions concerning such interventions remain. For example, because frailty syndrome is an independent predictor of a decline in cognitive function and is also associated with impaired physical outcomes (i.e., altered gait velocity and muscle weakness), the effects of high-velocity strength training intervention on executive function and cognitive impairment in the frail elderly population should also be further explored.

Transparency

Declaration of funding

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Declarations of financial/other relationships

M.I. and E.L.C. have disclosed that they have no significant relationships with or financial interests in any commercial companies related to this study or article. CMRO peer reviewers on this manuscript have no relevant financial or other relationships to disclose.

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