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Influence of strength training intensity on subsequent recovery in elderly

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ABSTRACT

Understanding the influence of strength training intensity on subsequent recovery in elderly is important to avoid reductions in physical function during the days following training. Twenty-two elderly were randomized in two groups: G70 (65.9 ± 4.8 years, $n = 11$) and G95 (66.9 ± 5.1, n = 11). Baseline tests included maximum voluntary isometric contraction (peak torque and rate of torque development - RTD), countermovement jump, and functional capacity (timed up and go, stairs ascent and descent). Then, both groups performed a single strength training session with intensities of 70% (G70) or 95% (G95) of five repetition maximum. The same tests were repeated immediately, 24 h, 48 h, and 72 h after the session. Peak torque was lower than baseline immediately after for both groups and at 24 h for G95. Compared with G70, G95 had lower peak torque at 24 h and 48 h. Countermovement jump, timed up and go, stairs ascent, and RTD at 0–50 ms only differed from baseline immediately after for both groups. RTD at 0–200 ms was lower than baseline immediately after and 24 h after the session for both groups. In conclusion, reduced physical function immediately after strength training can last for 1–2 days in elderly depending on the type of physical function and intensity of training. Higher intensity resulted in greater impairment. Exercise prescription in elderly should take this into account, e.g., by gradually increasing intensity during the first months of strength training. These results have relevance for elderly who have to be fit for work or other activities in the days following strength training.

1. Introduction

Since the 1970s there has been a steady rise in the proportion of elderly people in most parts of the world (OECD, 2016). This has important socioeconomic consequences as the number of economically inactive people continues to rise. One of the consequences is that people in many parts of the world are expected to stay at the labor market until a higher age (Eläketurvakeskus, 2017). However, the inherent decline in muscle function (i.e., maximum strength, power, explosive force, and functional capacity) with aging may impede this ambition (Byrne et al., 2016; Izquierdo et al., 1999; Manini and Clark, 2012; McKinnon et al., 2017). The decrease in physical capacity with age may make it more difficult to meet the work demands, and effective methods for maintaining muscle strength with aging are therefore important.

Strength training is a widely used method for improving and maintaining muscle strength, power, and hypertrophy among all age groups. In the older population, strength training is efficient to attenuate and even reverse the deleterious effects of aging in the neural and muscular function, as evidenced through physiological and biomechanical adaptations such as increases in neural drive (Unhjem et al., 2015), voluntary activation (Arnold and Bautmans, 2014), motor unit firing rate (Kamen and Knight, 2004), and muscle hypertrophy (Lixandrão et al., 2016). These adaptations can result in gains of muscle power as well as maximum and explosive strength, which provides improvements of stabilization during standing, locomotion, or in response to mechanical perturbation (Izquierdo et al., 1999; Pijnappels et al., 2008), in functional capacity of daily living activities performance, reducing risk of falls (Bento et al., 2010; Byrne et al., 2016; Moura et al., 2017), and maintenance of work ability among workers with hard physical labor (Jakobsen et al., 2015; Sundstrup et al., 2014).

Despite the numerous beneficial long-term adaptations, the acute response to high-intensity strength training can be viewed as “damaging” from a muscle cellular point of view. The mechanical overload produced by successive concentric and especially eccentric actions during unaccustomed strength training damages contractile proteins, intermediate filaments, and connective tissue surrounding the muscle

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fibers (Lau et al., 2013). This initiates an inflammatory process and causes delayed onset muscle soreness, increasing muscle stiffness and swelling (Clarkson and Hubal, 2002), and concomitant reductions in maximum voluntary contraction force (Dedrick and Clarkson, 1990), explosive force (Peñailillo et al., 2015), power (Byrne et al., 2004), and flexibility (Nogueira et al., 2014). Elderly people experience greater muscle damage (Manfredi et al., 1991) and need longer time for recovery (Dedrick and Clarkson, 1990) compared with younger people. Considering that many elderly people already have reduced physical function relatively to younger people, this can have important consequences for daily living activities and work ability. Thus, recommendations for elderly initiating strength training programs should consider not only long-term but also acute effects of different training regimens.

Studies investigating muscle damage in elderly have mainly used eccentric muscle actions, causing a great impairment on the neuromuscular properties (Dedrick and Clarkson, 1990; Lavender and Nosaka, 2006; Nogueira et al., 2014). By contrast, traditional strength training intensity is determined by concentric strength (i.e., one repetition maximum – 1-RM), which is relatively lower compared with eccentric strength (Weir et al., 1995). In this way, muscle damage following traditional strength training may be different from eccentric induced muscle damage. Studies in elderly inducing muscle damage using high-volume strength training (Roth et al., 1999, 2000) and an eccentric cycle ergometer (Manfredi et al., 1991) have investigated muscular structural changes, but not physical function and strength. Ferri et al. (2006) investigated muscle damage in the calf muscles of elderly performing unaccustomed strength training consisting of 10 sets with 10 repetitions at 70% of 1-RM, but did not investigate impairment in functional capacity. Different combinations of strength training variables (i.e., intensity, volume, rest intervals, and frequency), training level, targeted muscles (Brentano et al., 2016; Ferri et al., 2006; Nogueira et al., 2014; Roth et al., 1999, 2000) affect the muscle damage response. Training intensity is one of the key variables being manipulated. A recent strength training study comparing low and high intensities (20 vs 80% of 1-RM) found similar muscle hypertrophic effects in elderly, but the high intensity resulted in greater strength gains (Van Roie et al., 2013). Training intensities ranging from 60 to 85% of 1-RM are generally known to be effective for increasing muscle mass and strength (Mayer et al., 2011). From a safety point of view, the lower end of the intensity spectrum may be preferable to avoid overload injuries in unaccustomed elderly initiating strength training. Nevertheless, it is unclear how low/moderate intensity (60–69% of 1-RM) and high intensity (> 80% of 1-RM) (Peterson et al., 2010) differ from each other regarding acute muscle damage and functional responses after a single session of strength training.

Because the acute damaging response of unaccustomed strength training may negatively affect function and work ability in elderly people, thoroughly investigating acute changes in strength, power, function, and recovery time is vital for being able to provide optimal recommendations. Therefore, the purpose of this study is to compare the effects of different intensities of strength training programs to concentric failure in the lower limb muscles power, maximum and explosive force, functional capacity impairment, and recovery time in elderly.

2. Methods

2.1. Subjects

Subjects were recruited from our laboratory's participant database of previous strength training experiments. To be included, volunteers should be at least 60 years and able to complete the training session and all the tests. Exclusion criteria were current participation in structured traditional strength training and/or other exercises that involve strength or eccentric components (such as sports, high intensity running or cycling) in the last three months prior to the study, lower limb musculoskeletal and/or neuromuscular disease or chronic pain, unstable cardiovascular disease, and being unable to perform the exercises to concentric failure. In this way we could ensure that the training intensities would be as high as intended.

Twenty-five healthy elderly volunteered to participate in the present study and after three were excluded, 22 were eligible for the experiment. The reasons for excluding the three subjects were: unavailability to perform all the tests ($n = 1$) and lower limb discomfort (none with diagnosed disease – $n = 2$). Subjects were randomized in two groups: Moderate intensity group (G70, $n = 11$, ♀ = 4 and ♂ = 7; 65.9 ± 4.8 years; 75.1 ± 11.9 kg, and 32.2 ± 6.7% body fat) and high intensity group (G95, n = 11, ♀ = 3 and ♂ = 8; 66.9 ± 5.1 years; 73.5 ± 16.3 kg, and 31.3 ± 7.1% body fat). Subjects were requested to avoid any exercise, to not take anti-inflammatory drugs or dietary supplements and to not change their lifestyle during the experimental period. All volunteers gave written informed consent, and the study was approved by the local Human Research Ethics Committee (approval number: 1.657.414) and in accordance with the Helsinki declaration.

2.2. Study design

This study consisted of nine laboratory visits (i.e., 2 weeks). During the first visit, subjects were informed about study design and procedures. Subsequently, subjects were randomized in two groups; G70 and G95 (i.e. simple randomization). During the second visit, subjects reported to the laboratory for body composition assessment. During the next three visits, each separated by 48 (± 1) hours, subjects were familiarized, tested and retested in the following tests: (1) maximum voluntary isometric contraction (MVIC), (2) countermovement jump, (3) functional capacity, and (4) five-repetitions maximum (5-RM) for baseline values. During the sixth visit, each subject completed a single strength training session of either G70 or G95, depending on the randomized allocation. After 10 min following the 5-RM tests, each subject performed MVIC, countermovement jump, and functional capacity tests. Subjects repeated MVIC, countermovement jump, and functional capacity tests in the subsequent days (i.e., 24 ± 1, 48 ± 1, and 72 ± 1 h). All tests were performed by the same experienced evaluators.

2.3. Body composition

Subjects body composition were assessed by a trained evaluator with a dual-energy X-ray absorptiometry (DXA) (Lunar Prodigy Advance, GE Medical System Lunar, Madison, WI, USA), that were daily and weekly calibrated as recommended by the manufacturer. Height was measured using a standing stadiometer (Alturexata, Minas Gerais, Brazil) and body mass by a digital scale (Welmy W200, São Paulo, Brazil), with 0.1 cm and 0.1 kg resolution, respectively.

2.4. Maximum voluntary isometric contraction

Subjects performed a general warm-up of 5 min using cycle ergometer. Thereafter, subjects were firmly secured by inelastic straps about the trunk, hips, thighs, and ankle followed by a pre-conditioning to the dynamometer with 10 submaximal repetitions of concentric knee extension and flexion ($120°\cdot s^{-1}$) and three isometric attempts from submaximal to near-maximal efforts (60 s of rest between them). MVIC contractions were performed for the knee extensors at a static knee joint angle of 70° and hip angle of 85° (0° = knee full extension and hip in neutral position) using a daily calibrated isokinetic dynamometer (Biodex System 4, Biodex Medical Systems, Shirley, NY, USA). Hereafter, each subject performed three to four maximal trials