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Resistance training performed at distinct angular velocities elicits velocity-specific alterations in muscle strength and mobility status in older adults

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ABSTRACT

Background: The purpose of this study was to compare the effects of high and low velocity knee extension training on changes in muscle strength and mobility status in high-functioning older adults.
Methods: Twenty-six (16 female, 10 male) older adults (mean age of 65) were randomized to either 6 weeks of low velocity resistance training (LVRT) performed at 75°/s or high velocity resistance training (HVRT) performed at 240°/s. Both groups performed 3 sets of knee extension exercises at maximal effort, 3 times a week. Muscle strength was assessed through a range of testing velocities on an isokinetic dynamometer. Mobility status was assessed with the short physical performance battery (SPPB) and myosin heavy chain (MyHC) transcript levels were quantified via qRT-PCR.
Results: From baseline to post-training, there were several significant ($P < 0.05$) differences in muscle strength and functional characteristics in LVRT (n = 13) and HVRT (n = 13) groups. From baseline to post-training, MyHC-α mRNA and MyHC-IIa mRNA showed a significant ($P < 0.05$) increase within HVRT but MyHC-IIx mRNA did not change significantly. Our results demonstrate HVRT provides a greater number of muscular enhancements when compared to LVRT, particularly under conditions of high velocity muscle contraction.
Conclusion: HVRT is emerging as the optimal training stimulus for the older adult. The present study demonstrates, in addition to increased strength and functional outcomes, HVRT elicits a potentially therapeutic (i.e., slow to fast) transcriptional response in MyHC.

1. Introduction

Limitations in mobility, characterized as difficulty in performing ambulatory or physical tasks, affects 58% and 93% of non-frail and frail older adults, respectively (Gale et al., 2015). Limitations in mobility eventually lead to mobility disability which, due to its high prevalence, has become recognized by clinicians as an important geriatric syndrome (Gale et al., 2015; Freedman and Spillman, 2014; Rosso et al., 2013). Mobility difficulty decreases quality of life and is associated with increased health care resource utilization (Hardy et al., 2011; Chan et al., 2002). Furthermore, older adults who are able to maintain ambulation have lower rates of future disability, morbidity and mortality, and are better able to maintain their independence (Hardy et al., 2011; Fried and Guralnik, 1997; Jette and Branch, 1981). As the number of Americans aged 65 and older is projected to double by 2050 to approximately 89 million people (CDC; http://www.cdc.gov/aging/index.html), there will likely be a concomitant increase in the prevalence of mobility limitations and disability. Identifying interventions which most efficaciously inhibit the onset of mobility difficulty will help to promote healthy aging and reduce excess costs to the health care system.

Although mobility impairment is multifactorial in its etiology, age-related declines in muscle mass, strength, and power are important contributing factors (Janssen et al., 2002; Newman et al., 2006; Reid and Fielding, 2012). Reductions in muscle mass with age are largely attributed to a fiber-type specific atrophying of Type-2 (fast) fibers, thus inducing the adoption of a Type-1 (slow) phenotype within the musculature (Nilwik et al., 2013; Lexell, 1995). This fast to slow shift in muscle morphology directly contributes to a marked decline in the power producing capacity of the muscular system, a physiological characteristic which plays a critical role in mobility status (Reid and Fielding, 2012; Larsson et al., 1979; Pearson et al., 2006).

Many resistance training (RT) interventions have been designed to improve muscle function and delay mobility disability in older adults (Liu and Latham, 2009). Classically, low velocity resistance training (LVRT) regimens involving slow contraction of skeletal muscles against the mechanical load have been utilized. LVRT commonly leads to increased muscular strength and improvement in certain functional

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tasks (Latham et al., 2004). More recently, training with lower relative loads and faster movement speeds, known as power training or high velocity resistance training (HVRT), has been found to enhance muscle power and mobility status more effectively than LVRT (Reid and Fielding, 2012; Fielding et al., 2002; Marsh et al., 2009). While myosin heavy chain (MyHC) transcript expression has been investigated in response to LVRT, the transcriptional events which take place within senescent muscle in response to training at higher movement speeds remain unclear. Determining the extent to which transcriptional and functional outcomes are influenced by force-velocity parameters can help to optimize the design of resistance training programs which aim to have therapeutic or preventive effects on the older adult population.

Therefore, the purpose of this study was to assess the extent to which the changes in muscle function in older adults differ in response to 6 weeks of isokinetic training with either high velocity (240°/s, HVRT) or low velocity (75°/s, LVRT) muscle contractions. A secondary aim of this study was to investigate the effect of HVRT on MyHC transcript expression. We hypothesized that, compared to LVRT, HVRT would lead to more favorable muscle strength and functional outcomes and an upregulation of fast MyHC mRNA.

2. Materials and methods

2.1. Study design

This study was a single blind, randomized trial. Subjects were randomly assigned to 6 weeks of either low velocity resistance training (LVRT) or high velocity resistance training (HVRT). Subjects underwent pre- and post-training strength and functional testing. A subsample of subjects (criteria identified below) also underwent subcutaneous needle biopsies of the vastus lateralis pre- and post-training.

The first visit that subjects made to the laboratory was a familiarization session. The next visit was to undergo the initial muscle biopsy procedure and, 3 days later, subjects returned for baseline strength and functional testing. Two days after this testing, subjects began the 6 weeks of resistance training. Two days after the final training session, subjects underwent the post-training biopsy procedure and, two to three days after the biopsy, the subjects completed the post-training strength and functional testing. Subjects were asked to maintain all prior physical activity and dietary habits and not to partake in any form of lower body resistance training outside of the study.

2.2. Subjects

Subjects were recruited through advertisements and email. Potential subjects were initially screened by telephone or in person. To be eligible for the resistance training portion of the study, subjects needed to be age 60 or older, apparently healthy based on self-reported medical history, recreationally active, and not have participated in structured progressive resistance training within the previous 6 months. Exclusion criteria included any preexisting condition that would inhibit successful participation in the exercise program, such as cardiovascular disease, musculoskeletal disorders, and neurological or cognitive impairment. Exclusion criteria for the biopsy portion of the study included cardiovascular, neurological or musculoskeletal disease; a history of bleeding disorders; taking any anticoagulant medications, or other medications that affect blood clotting. Written, informed consent was obtained from each participant after all procedures were approved by the Institutional Review Board of Iowa State University. Gender, age, height, body weight and BMI are in Table 1. The racial distribution of the participants was 100% Caucasian.

2.3. High and low velocity resistance training interventions

Resistance training was performed 3 times a week for 6 weeks. Each resistance training session was separated by at least 48 h. Resistance training sessions consisted of performing knee extensions independently with both legs, emphasizing the vastus intermedius, vastus medialis, vastus lateralis and rectus femoris. For each leg, subjects performed 3 consecutive sets of 8 repetitions with 3–4 s between repetitions and 3 min between sets, on a calibrated Biodex Multi-Joint System Pro dynamometer (Biodex Medical Systems, Shirley, NY). Subjects assigned to LVRT performed each repetition at an angular velocity of 75°/s. Subjects assigned to HVRT performed each repetition at an angular velocity of 240°/s.

Table 1
Anthropometric data.

Group	n	n (f)	n (m)	Age (yr)	Height (cm)	Body weight (kg)	BMI	SPPB
LVRT	13	8	5	65.1 ± 6.7	171.1 ± 7.8	80.0 ± 13.8	27.3 ± 4.0	11.6 ± 1.4
HVRT	13	8	5	64.5 ± 2.4	170.4 ± 8.2	79.1 ± 17.5	27.1 ± 4.7	11.6 ± 1.4

Values are means ± SD; n, no. of subjects; f, female; m, male; BMI, body mass index; SPPB, short physical performance battery.

2.4. Muscle performance measurements

2.4.1. Isokinetic strength testing

Concentric, isokinetic knee extensions were performed on the dominant leg at ordered velocities of 75, 180, and 240°/s. Peak torque, maximal repetition work, total work, torque at 0.2 s, the rate of force development, average power, and peak power were measured at each velocity using a calibrated dynamometer (Biodex Medical Systems, Shirley, NY). Subjects were seated with a restraining strap over the pelvis and trunk in accordance with the manufacturer's guidelines. The input axis of the dynamometer was aligned with the axis of the knee and the non-working leg was braced against the contralateral-limb stabilization bar. Three submaximal warm-up trials preceded 3 consecutive maximal muscle actions at each velocity, with the highest value selected as the representative score. A 4 min rest was allowed between testing at each velocity.

2.5. Functional measurements

2.5.1. Short physical performance battery (SPPB)

The SPPB is a valid and reliable test which assesses balance, habitual gait speed, and the ability to rise from a chair. Taken together, these results are highly predictive of future disability, loss of independence, and mortality (Guralnik et al., 1994).

2.5.2. 8-foot up-and-go

The 8-foot up-and-go assesses the ability to stand up from a chair, walk a distance of 8 ft, turn, walk back to the chair, and sit down again. This test is a measure of physical mobility and demonstrates a subject's balance, gait speed, and functional ability. It is a useful predictor of falls in community-dwelling older adults (Okumiya et al., 1998).

2.6. Biochemical measurements

2.6.1. Muscle biopsy

A percutaneous biopsy was obtained using a 5 mm Bergström needle, under local anesthesia from the vastus lateralis muscle of the dominant leg. The muscle samples (~40 mg of tissue) were removed, immediately frozen in liquid nitrogen, and then stored at −80 °C. Biopsies were obtained at rest and on non-training days, 3 to 4 days before baseline testing and 2 days after the final training session. The post-training biopsy was obtained from the same leg, 3–4 cm distal to the site of the pre-training biopsy.