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Resistance training improves capacity to delay neuromuscular fatigue in older adults

Nadia S. Emerson, Jeffrey R. Stout *, David H. Fukuda, Edward H. Robinson, Iv, Tyler C. Scanlon, Kyle S. Beyer, Maren S. Fragala, Jay R. Hoffman

Institute of Exercise Physiology and Wellness, University of Central Florida, 4000 Central Florida Blvd, Orlando, FL 32816, United States

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ABSTRACT

The purpose of this study was to investigate the effects of short term resistance exercise on neuromuscular fatigue threshold (PWC_{FT}), strength, functional performance, and body composition in older adults. Twenty-three participants (71.2 ± 6.0 yr) were randomly assigned to 6 weeks of resistance exercise (EXE) or control (CONT). A submaximal cycle ergometer test, physical working capacity at fatigue threshold, was used to determine PWC_{FT}. Strength was assessed with predicted leg extension 1-RM and functional performance with time to complete 5 chair rises (CHAIR) and walk an 8-ft course (WALK). PWC_{FT}, 1-RM and CHAIR significantly ($p < 0.05$) improved in the EXE (27%, 24%, 27%) compared with CONT (−0.1%, 7%, 6%), respectively. The results of this study suggest that short term EXE improved strength, functionality and the capacity to delay the onset of neuromuscular fatigue in older adults.

1. Introduction

Aging is often associated with progressive loss of neuromuscular function (NMF) that may lead to disability and loss of independence. (Aagard, Suetta, Caserotti, Magnusson, & Kjaer, 2010). After age 50, skeletal muscle mass declines at an annual rate of 1–2% with a concomitant loss of strength at 1.5% each year and which accelerates to 3% per year after age 60 (Hughes, Frontera, Roubenhoff, Evans, & Singh, 2002; Hughes et al., 2001). This age-acquired deficit, known as sarcopenia, places an increased burden of work on existing skeletal muscle and may lead to the early onset of neuromuscular fatigue during activities of daily living. Leisure activity is not enough to prevent sarcopenia, but resistance exercise (RE) has been identified as an effective countermeasure for regaining neuromuscular capacity and function in the aging adult (Aagard et al., 2010; Raguso et al., 2006).

Progressive RE is considered to be the preferred approach to elicit neuromuscular adaptations for healthy older adults (Aagard et al., 2010; Peterson, Rhea, Sen, & Gordon, 2010). Early improvements to RE are thought to be the result of neural adaptations through improved motor coordination and efficiency (Moritani & deVries, 1979); however, the extent to which RE effects NMF has not been widely investigated. deVries et al. (1989) and Wojcik, Thelen, Schultz, Ashton-Miller, and Alexander (2001) have suggested that falls may be related to fatigue-induced deterioration of motor coordination. Thus, an improved resistance to fatigue with RE, may be important to consider when working with an older population.

The use of electromyographic (EMG) techniques has allowed observation of age-related changes in neuromuscular function (Boccia, Dardanello, Rosso, Pizzigalli, & Rainoldi, 2014). It has previously been shown that electrical activity in muscle tissue increases as a function of time when the muscle works against a constant force during isometric or dynamic activity (deVries, 1968; Lippold, Redfearn, & Vučo, 1960; Petrofsky, 1979). This increase in electrical activity is thought to occur as fatigue progresses as a result of greater recruitment and higher innervation rate to make up for force losses as motor units fatigue (deVries et al., 1987; deVries & Housh, 1994). deVries et al. (1987) developed a submaximal, discontinuous cycle ergometer test which utilizes EMG to objectively measure the first sign of neuromuscular fatigue, known as the physical working capacity at fatigue threshold (PWC_{FT}).

The PWC_{FT} represents the highest power output that does not result in a significant increase in electrical activity of the thigh muscle during cycling. This test is unique in that it measures the work capacity that can be maintained before the onset of neuromuscular fatigue rather than the duration a given bout of exercise can be maintained, which may be largely influenced by subjective decisions on the part of the participant and the

* Corresponding author. Tel.: +1 407 823 0211; fax: +1 407 823 2368.
E-mail address: Jeffrey.Stout@ucf.edu (J.R. Stout).

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investigator (deVries & Housh, 1994). The PWC_{FT} has been associated with measures of aerobic power, muscular endurance and efficiency, which are more commonly measured by oxygen consumption rate (VO_2) during tests of maximal exertion (deVries et al., 1989). Recently, Emerson et al. (2014) demonstrated a significant relationship between PWC_{FT} and both sarcopenia-related body composition and functionality measures in older adults. Further, Stout et al. (2015) reported a significant inverse relationship between PWC_{FT} and C-terminal agrin fragment (CAF) in older men. Serum CAF has been shown to be inversely associated with lean body mass and proposed to be a potential marker of neuromuscular junction degeneration in older men (Drey et al., 2013). The PWC_{FT}, therefore, may be a non-invasive, submaximal method that is associated with neuromuscular junction health. In addition, deVries et al. (1989) suggested that the PWC_{FT} may be more appropriate and sensitive to the effects of training in older adults than other continuous graded exercise tests (GXTs) that require maximal effort (i.e., VO_2max) and may be ill advised or hazardous for this population.

Previous research has investigated the effects of aerobic training and/or nutritional supplementation on the PWC_{FT} in older adults (deVries et al., 1989; McCormack et al., 2013; Stout et al., 2007a, 2007b, 2008). deVries et al. (1989) reported a 29.8% and 38.4% improvement in PWC_{FT} following 10 weeks of low (70% of pretest PWC_{FT} values) or high (85% of pretest PWC_{FT} values) intensity aerobic training in older adults. Older adults have shown to exhibit improvements in PWC_{FT} between 13% and 30% through the use of various ergogenic aids, including creatine and beta-alanine (Stout et al., 2007a, 2007b, 2008; McCormack et al., 2013).

Despite the supporting evidence for the use of RE as a countermeasure for the age-related neuromuscular decline, the effects of RE on PWC_{FT} have yet to be investigated. Therefore the primary purpose of this study was to evaluate the effects of 6 weeks of progressive RE on the neuromuscular fatigue threshold in older adults. In addition, this investigation examined the effect of RE on body composition, strength and functional performance measures.

2. Methods

2.1. Participants

Twenty-three healthy men and women over the age of 60 years (Table 1), living independently in Central Florida, volunteered to participate in this study. Prior to testing, all volunteers were cleared for participation by medical history questionnaire and physical activity readiness questionnaire, or physician clearance. No participants had major surgery within the previous 6 months, or a history of asthma, heart or pulmonary disease, uncontrolled hypertension, or were taking any medications that would interfere with exercise. At the beginning of the study, all participants were advised of any possible risks before providing their written informed consent. All procedures were approved by the University Institutional Review Board.

Table 1
Participant characteristics.

		Age (yr)	Height (cm)	Body mass (kg)
EXE ($n = 11$)	Pre	72.1 ± 6.6	168.8 ± 8.5	78.5 ± 15.2
	Post			78.9 ± 16.7
CONT ($n = 12$)	Pre	70.3 ± 5.6	166.5 ± 7.9	76.6 ± 18.3
	Post			76.8 ± 18.5

Values reported as mean ± standard deviation (SD); EXE—exercise, CONT—control.

2.2. Study design

This study followed a randomized, between groups, repeated measures design consisting of two groups: exercise (EXE) and control (CONT). The volunteers participated in initial testing, underwent 6 weeks of an exercise intervention or control period, and completed post-treatment testing.

Group randomization was based upon the participant's availability and willingness to attend the training sessions during the 6 week period. Participants assigned to the EXE group underwent 6 weeks of resistance training. Participants in the CONT group were instructed to maintain their current activity status for the following 6-weeks.

2.3. Measures

Testing occurred on two separate days, approximately 24 h apart. On the first testing day, participants reported to the laboratory after an overnight fast for body composition assessment. On the second testing day, participants completed the performance tests in the following order: PWC_{FT}, CHAIR, WALK, and 1RM. Participants were advised to maintain a similar daily routine on testing dates.

2.4. Body composition

Whole body-dual energy X-ray absorptiometry (DEXA) scans (ProdigyTM; Lunar Corporation, Madison, WI) was used to assess body composition. Total body estimates of fat mass (FM), and non-bone lean tissue (LM) were determined using the company's recommended procedures and supplied algorithms. Quality assurance was assessed by daily calibrations and was performed prior to all scans using a calibration block provided by the manufacturer. Previously determined intraclass correlation coefficients (ICC) and standard errors of measurement (SEM) for test–retest reliability for 11 men and women 24–48 h apart for total FM and LM were ICC = 0.97, SEM ± 0.93 kg, and ICC = 0.99, SEM ± 0.61 kg, respectively.

2.5. Electromyographic (EMG) measurements

A bipolar (4.6 cm center-to-center) surface electrode (Quinton Quick-Prep silver-silver chloride) arrangement was placed over the right vastus lateralis muscle, at approximately 60% of the distance from the lateral portion of the patella on a line with the greater trochanter. The reference electrode was placed over the lateral epicondyle of the distal femur. Inter-electrode impedance was kept below 5,000 ohms with abrasion of the skin beneath the electrodes. The raw EMG signal was sampled at 1 kHz, differentially amplified (EMG 100c, bandwidth = 10–500 Hz, gain: ×1000; MP150 BIOPAC Systems, Inc., Santa Barbara, CA), and digitally bandpass filtered (zero-phase shift fourth-order Butterworth) at 10–500 Hz. The signals were recorded and stored on a personal computer (Dell Latitude E6530, Dell Inc., Round Rock, TX) for off-line analysis. The EMG signals were expressed as root mean square (rms) amplitude values (μVrms) and analyzed with custom-written software (LabView, National Instruments Corporation, Austin, TX).

2.6. Physical working capacity at fatigue threshold test

The estimate of PWC_{FT} values during the 2-min discontinuous incremental cycle ergometer test was determined using the procedures adapted from deVries et al. (1987, 1989). The initial work rate was set at 30 W and increased 15 W for each stage. The subjects pedaled at 50 revolutions per minute (rpm) for each 2-min stage of the test on an electronically-braked cycle ergometer (Lode,