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Original Study

There Are No Nonresponders to Resistance-Type Exercise Training in Older Men and Women

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ABSTRACT

Objective: To assess the proposed prevalence of unresponsiveness of older men and women to augment lean body mass, muscle fiber size, muscle strength, and/or physical function following prolonged resistance-type exercise training.

Design/Setting/Participants: A retrospective analysis of the adaptive response to 12 (n = 110) and 24 (n = 85) weeks of supervised resistance-type exercise training in older (>65 years) men and women.

Measurements: Lean body mass (DXA), type I and type II muscle fiber size (biopsy), leg strength (1-RM on leg press and leg extension), and physical function (chair-rise time) were assessed at baseline, and after 12 and 24 weeks of resistance-type exercise training.

Results: Lean body mass increased by 0.9 ± 0.1 kg (range: −3.3 to +5.4 kg; $P < .001$) from 0 to 12 weeks of training. From 0 to 24 weeks, lean body mass increased by 1.1 ± 0.2 kg (range: −1.8 to +9.2 kg; $P < .001$). Type I and II muscle fiber size increased by 324 ± 137 μm^2 (range: −4458 to +3386 μm^2; $P = .021$), and 701 ± 137 μm^2 (range: −4041 to +3904 μm^2; $P < .001$) from 0 to 12 weeks. From 0 to 24 weeks, type I and II muscle fiber size increased by 360 ± 157 μm^2 (range: −3531 to +3426 μm^2; $P = .026$) and 779 ± 161 μm^2 (range: −2728 to +3815 μm^2; $P < .001$). The 1-RM strength on the leg press and leg extension increased by 33 ± 2 kg (range: −36 to +87 kg; $P < .001$) and 20 ± 1 kg (range: −22 to +56 kg; $P < .001$) from 0 to 12 weeks. From 0 to 24 weeks, leg press and leg extension 1-RM increased by 50 ± 3 kg (range: −28 to +145 kg; $P < .001$) and 29 ± 2 kg (range: −19 to +60 kg; $P < .001$). Chair-rise time decreased by 1.3 ± 0.4 seconds (range: +21.6 to −12.5 seconds; $P = .003$) from 0 to 12 weeks. From 0 to 24 weeks, chair-rise time decreased by 2.3 ± 0.4 seconds (range: +10.5 to −23.0 seconds; $P < .001$). Nonresponsiveness was not apparent in any subject, as a positive adaptive response on at least one training outcome was apparent in every subject.

Conclusions: A large heterogeneity was apparent in the adaptive response to prolonged resistance-type exercise training when changes in lean body mass, muscle fiber size, strength, and physical function were assessed in older men and women. The level of responsiveness was strongly affected by the duration of the exercise intervention, with more positive responses following more prolonged exercise training. We conclude that there are no nonresponders to the benefits of resistance-type exercise training on lean body mass, fiber size, strength, or function in the older population. Consequently, resistance-type exercise should be promoted without restriction to support healthy aging in the older population.

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Aging is associated with a progressive decline in skeletal muscle mass, strength, and physical function, a condition termed *sarcopenia*.[1] Sarcopenia is an independent risk factor for adverse outcomes, including difficulties in carrying out activities of daily living, falls, fractures, hospitalization and readmission, and death.[2] Resistance-type exercise training currently represents the primary therapeutic strategy recommended to prevent and reverse the age-related decline in skeletal muscle mass, strength, and function.[3] Current public health recommendations for older adults (>65 years) in both Canada and the United States prescribe 150 minutes of moderate-to vigorous-intensity physical activity to be accumulated per week, with additional muscle strengthening activities performed twice weekly.[4,5] In further support of the benefits of resistance-type exercise training in the older population, a recent systematic review of the literature confirmed that even the very old (>75 years) retain the capacity for muscle hypertrophy and increased strength in response to exercise training.[6] However, previous work has shown substantial interindividual variability in resistance-type exercise-mediated changes in muscle mass[7–9] and strength[8] after a period of standardized exercise training. In response to both resistance-[8,9] and endurance-type exercise training,[10–12] some individuals seem to demonstrate exceptionally large responses when assessed on a given training outcome, whereas others show only a minimal or even an apparent opposite response to prolonged exercise training. However, although some individuals may show no response or even an opposite response[13] on a single training outcome in response to exercise training, other critically important physiological variables may be improved in those individuals after training. Therefore, a wide range of response outcomes must be examined to fully evaluate the efficacy of a resistance training program on participants' health.[14,15] If a large proportion of the older population is indeed unresponsive to the effects of resistance-type exercise training on muscle mass, strength, and function, it would be important to identify and possibly even characterize these individuals for alternate treatment strategies. Currently, no studies have examined the prevalence of unresponsiveness to prolonged resistance-type exercise training–mediated improvements in lean body mass, muscle fiber size, muscle strength, and physical function in the older population. The aim of the present study was to examine the responsiveness to prolonged resistance-type exercise on multiple training outcomes, including lean body mass, muscle fiber size, muscle strength, and physical function after 12 to 24 weeks of training in a large group of older men and women.[16–18] We hypothesized that despite substantial interindividual variability in the adaptive response to resistance-type exercise training, there are no nonresponders to the impact of resistance-type exercise training on increasing lean body mass, muscle fiber size, strength, and/or physical function.

Methods

Participants

The participant population included healthy,[16,18] prefrail, and frail older[17] men and woman (>65 years). Individuals with cancer, chronic obstructive pulmonary disease, muscle disease, and those unable to perform exercise because of orthopedic limitations were excluded from the study. Individuals with type 2 diabetes (blood glucose >7.0 mmol/L) and renal insufficiency (estimated glomerular filtration rate <60 mL/min/1.73 m^2) also were excluded. All participants were living independently. None of the individuals had a history of participating in any structured exercise training program designed to improve performance over the past 5 years. All participants were informed of the nature and associated risks of the experimental procedures of each respective study before obtaining their written informed consent.

Study Design

Individuals participated in either a 12-[16] or 24-week[17,18] program of personally supervised resistance-type exercise training. The primary outcome variables in the current analysis included lean body mass, type I and type II muscle fiber size, muscle strength, and physical function. Lean body mass was assessed by dual-energy X-ray absorptiometry (DXA), type I and type II muscle fiber size was assessed by needle biopsy and subsequent immunohistochemistry, muscle strength was assessed by evaluation of single repetition maximum (1-RM) in both the leg press and leg extension, and physical function was assessed by repeated chair-rise time (sit-to-stand) respectively.

Resistance-Type Exercise Training Program

The resistance-type exercise training was carried out under supervision of a trained investigator either 2[17] or 3[16,18] times per week and performed for 12[16] and 24[17,18] weeks, respectively. The 24-week training intervention[17,18] consisted of evaluation at 12 weeks; these data are included in the present analysis. The details of the exercise training programs including the exercise equipment, exercise selection, number of sets, number of repetitions, interest rest-intervals, and intensity progression (as a percentage of 1-RM maximum) have been described in detail previously.[16–18]

Lean Body Mass, Muscle Fiber Size, Maximum Strength, and Physical Function

Lean body mass was assessed in the fasted state via DXA (Lunar Prodigy Advance; GE Health Care, Madison, WI[17] and Hologic, Discovery A; QDR Series, Bradford, MA).[16,18] All participants underwent a muscle biopsy from the vastus lateralis 3 days before initiating the resistance-type exercise training program and 4 days after the 12- and 24-week strength assessments in the overnight fasted state. Maximum strength was assessed via evaluation of 1-RM on a leg press and leg-extension machine (Technogym, Rotterdam, the Netherlands). All 1-RM tests were preceded by a separate familiarization session during which the proper exercise technique was practiced and maximum strength was estimated. In a second session, 1-RM strength was determined as previously described.[19] The 1-RM testing is preferred to evaluate changes in muscle strength during resistance-type exercise training.[19] Physical function was assessed via a sit-to-stand test. Briefly, for the sit-to-stand test, participants were instructed to fold their arms across their chest and stand up/sit down 5 times, as fast as possible, from a seat at 0.42 m from the floor. Time was recorded from the initial sitting to the final standing position. The fastest of 2 attempts was used for analysis.[20]

Statistics

The mean, minimum, and maximum values were calculated for the entire group, and within both men and women, for lean body mass, type I and II muscle fiber size, muscle strength (1-RM on both the leg press and leg extension), and physical function (sit-to-stand test). Differences (absolute changes) from 0 to 12 weeks and 0 to 24 weeks for each of the outcome measures were assessed using a 1-sample *t* test. Differences (absolute changes) between men and women from 0 to 12 and 0 to 24 weeks were examined using unpaired *t* tests. Statistical analyses were performed using IBM SPSS