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Original Study

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

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Keywords: Resistance exercise, sarcopenia, lean body mass, muscle strength, muscle function, aging

\textbf{A B S T R A C T}

\textbf{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 training.

\textbf{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.

\textbf{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.

\textbf{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 \textmu m\textsuperscript{2} (range: −1458 to +3386 \textmu m\textsuperscript{2}; P = .026) and 701 ± 137 \textmu m\textsuperscript{2} (range: −4041 to +3904 \textmu m\textsuperscript{2}; P < .001) from 0 to 12 weeks. From 0 to 24 weeks, type I and II muscle fiber size increased by 360 ± 157 \textmu m\textsuperscript{2} (range: −3531 to +3426 \textmu m\textsuperscript{2}; P = .026) and 779 ± 161 \textmu m\textsuperscript{2} (range: −2728 to +3815 \textmu m\textsuperscript{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.

\textbf{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. 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. 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. 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. 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. However, previous work has shown substantial interindividual variability in resistance-type exercise-mediated changes in muscle mass and strength after a period of standardized exercise training. In response to both resistance- and endurance-type exercise training, some individuals seem to demonstrate exceptionally large responses when assessed on a given training outcome, whereas others show only a minimal or no response even to prolonged exercise training. However, although some individuals may show no response or even an opposite response 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. 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. 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, prefrail, and frail older 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 m²) 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- or 24-week 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 or 3 times per week and performed for 12 and 24 weeks respectively. The 24-week training intervention 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.

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 and Hologic, Discovery A; QDR Series, Bradford, MA). 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. The 1-RM testing is preferred to evaluate changes in muscle strength during resistance-type exercise training. 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.

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 single 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.
sectional data was available for 66 participants at 24 weeks. Time consisted of 85 participants. Type I and type II was available for 92 participants at 12 weeks. The 24-week analysis of 1-RM leg press, and 1-RM leg extension had a lean body mass of 41.8 kg on 85 participants. Type I and type II analysis of lean body mass, 1-RM leg press, and 1-RM leg extension Absolute Changes in Lean Body Mass, Types I and II Muscle Fiber Size, Leg Strength, and Physical Function Participants

Before training, lean body mass averaged 52.3 ± 1.0 kg. Women had a lean body mass of 41.8 ± 0.7 kg, which was significantly lower (P < .001) compared with men who had a lean body mass of 59.3 ± 0.7 kg. After 12 weeks of training, there was a significant increase (P < .001) in lean body mass of 0.9 ± 0.1 kg. Men showed a 0.8 ± 0.1-kg increase, and women showed a 1.0 ± 0.2-kg increase (Tables 2 and 3), with no differences between groups (P = .50). After 24 weeks of training, the increase in lean body mass averaged 1.1 ± 0.2 kg (P < .001). Men demonstrated a 1.0 ± 0.2-kg increase in lean body mass, and women demonstrated a 1.2 ± 0.3-kg increase (P = .58 between groups). Histograms of individual changes in lean body mass (absolute changes from baseline) after 12 and 24 weeks of resistance-type exercise training are shown in Figure 1A and B, respectively.

Type I and II Fiber Size

Before training, type I and II fiber cross-sectional area (CSA) (μm²) was 5741 ± 147 μm² and 4540 ± 162 μm², respectively. Men had a type I fiber CSA of 6136 ± 174 μm² and type II fiber CSA of 5264 ± 166 μm², whereas women had a mean type I fiber CSA of 5063 ± 227 μm² and a type II fiber CSA of 3298 ± 209 μm². Pre-training muscle fiber size was significantly lower in women in both type I (P < .001) and type II (P < .001) fibers. After 12 weeks of training, there was an increase in type I (P = .021) and type II (P < .001) fiber CSA of 324 ± 137 μm² and 701 ± 137 μm², respectively. Men showed an increase of 451 ± 164 μm² and 1034 ± 172 μm², whereas women showed an increase of 97 ± 244 μm² and 108 ± 191 μm² in type I and II fiber size, respectively (Tables 2 and 3). There was no difference between men and women in the change in type I (P = .22) fiber size from 0 to 12 weeks; however, the change in type II fiber size was significantly greater in men compared with women (P < .001). From 0 to 24 weeks of training, the increase in type I and II fiber size was 360 ± 157 μm² (P = .026) and 779 ± 161 μm² (P < .001). Men showed an increase of 259 ± 213 μm² and 946 ± 265 μm² in type I and II fiber size, and women showed an increase of 473 ± 236 μm² and 589 ± 167 μm² (Tables 2 and 3). There were no differences between men and women in the change in type I (P = .50) or type II (P = .28) fiber size from 0 to 24 weeks. Histograms of individual changes in type I and type II fiber size (absolute changes from baseline) after 12 and 24 weeks of resistance-type exercise training are shown in Figures 2A and B, and 3A and B, respectively.

<table>
<thead>
<tr>
<th>Variable</th>
<th>12 wk</th>
<th>Minimum 12 wk</th>
<th>Maximum 12 wk</th>
<th>24 wk</th>
<th>Minimum 24 wk</th>
<th>Maximum 24 wk</th>
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<tr>
<td>Lean body mass, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.9 ± 0.1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Men</td>
<td>0.8 ± 0.1</td>
<td>−3.3</td>
<td>+3.4</td>
<td>1.0 ± 0.2</td>
<td>−1.8</td>
<td>+3.8</td>
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<tr>
<td>Women</td>
<td>1.0 ± 0.2</td>
<td>−1.2</td>
<td>+5.4</td>
<td>1.2 ± 0.3</td>
<td>−1.5</td>
<td>+9.2</td>
</tr>
<tr>
<td>Type I fiber size, μm²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>324 ± 137</td>
<td></td>
<td></td>
<td>360 ± 157</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>451 ± 164</td>
<td>−1694</td>
<td>+3170</td>
<td>259 ± 213</td>
<td>−3509</td>
<td>+2249</td>
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<tr>
<td>Women</td>
<td>97 ± 244</td>
<td>−4458</td>
<td>+3386</td>
<td>473 ± 236</td>
<td>−3531</td>
<td>+3426</td>
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<td></td>
<td></td>
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<tr>
<td>All</td>
<td>701 ± 137</td>
<td></td>
<td></td>
<td>779 ± 161</td>
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<td></td>
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<tr>
<td>Men</td>
<td>1034 ± 172</td>
<td>−3212</td>
<td>+3904</td>
<td>946 ± 265</td>
<td>−2728</td>
<td>+3815</td>
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<tr>
<td>Women</td>
<td>108 ± 191</td>
<td>−4041</td>
<td>+2010</td>
<td>589 ± 167</td>
<td>−1737</td>
<td>+1896</td>
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<td>1-RM leg press, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>All</td>
<td>33 ± 2</td>
<td></td>
<td></td>
<td>50 ± 3</td>
<td></td>
<td></td>
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<tr>
<td>Men</td>
<td>34 ± 2</td>
<td>+10</td>
<td>+75</td>
<td>53 ± 3</td>
<td>+24</td>
<td>+115</td>
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<tr>
<td>Women</td>
<td>31 ± 4</td>
<td>−36</td>
<td>+87</td>
<td>48 ± 4</td>
<td>−28</td>
<td>+145</td>
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<tr>
<td>1-RM leg extension, kg</td>
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<tr>
<td>All</td>
<td>20 ± 1</td>
<td></td>
<td></td>
<td>29 ± 2</td>
<td></td>
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<tr>
<td>Men</td>
<td>24 ± 1</td>
<td>0</td>
<td>+56</td>
<td>36 ± 2</td>
<td>+2</td>
<td>+57</td>
</tr>
<tr>
<td>Women</td>
<td>14 ± 2</td>
<td>−22</td>
<td>+45</td>
<td>22 ± 2</td>
<td>−19</td>
<td>+60</td>
</tr>
<tr>
<td>Chair-rise time, s</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>All</td>
<td>−1.3 ± 0.4</td>
<td></td>
<td></td>
<td>−2.3 ± 0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>−0.6 ± 0.6</td>
<td>+21.6</td>
<td>−6.0</td>
<td>−1.2 ± 0.4</td>
<td>+10.5</td>
<td>−6.3</td>
</tr>
<tr>
<td>Women</td>
<td>−1.9 ± 0.5</td>
<td>+3.1</td>
<td>−12.5</td>
<td>−3.2 ± 0.7</td>
<td>+2.3</td>
<td>−23.0</td>
</tr>
</tbody>
</table>
Histograms of individual changes in leg press and leg extension strength assessed on the leg press and leg extension, respectively (Tables 2 and 3). There were no differences between men and women in baseline chair-rise time (absolute change from baseline) after 12 and 24 weeks of resistance-type exercise training (P < .001). From 0 to 12 weeks of training, chair-rise time decreased by -1.2 ± 0.4 seconds (P = .003), with men and women demonstrating a decrease of -0.6 ± 0.6 seconds and -1.9 ± 0.5 seconds, respectively (Tables 2 and 3). There were no differences between men and women in the change in chair-rise time after 12 weeks of resistance-type training (P = .11). After 24 weeks of resistance-type training, the absolute change in chair-rise time was -2.3 ± 0.4 seconds (P < .001), with men and women demonstrating a decrease of -1.2 ± 0.4 seconds and -3.2 ± 0.7 seconds, respectively (Tables 2 and 3). The decrease in chair-rise time from 0 to 24 weeks was significantly greater in women as compared with men (P = .001). Histograms of individual changes in chair-rise time (absolute changes from baseline) after 12 and 24 weeks of resistance-type exercise training are shown in Figure 6A and B, respectively.

**Discussion**

In the present study, we observed that prolonged (12–24 weeks) resistance-type exercise training increased lean body mass, type I and II muscle fiber size, muscle strength, and physical function in a large group of older men and women; however, large interindividual variability in the measured changes in these training outcomes was observed (Figures 1–6). Despite the interindividual variability in the adaptive response to training, we were unable to identify a single participant who did not positively respond to resistance-type exercise training (Supplementary Tables 1 and 2). All participants demonstrated increases in at least one of the training outcomes (lean body mass, muscle fiber size, strength, and/or physical function) examined. Furthermore, we observed that the duration of resistance-type exercise training is an important factor determining an individual’s response to exercise training. In other words, there were individuals who demonstrated little to no improvements after 12 weeks of training, but showed a substantial improvement after 24 weeks of training.

Regular resistance-type exercise training has been well-established as an effective interventional strategy to increase skeletal muscle mass and strength in both elderly men and women,17,18,21 and has been shown to be accompanied by many favorable consequences on a variety of outcomes, including muscle mass, muscle strength, and physical function. These results underscore the importance of resistance-type exercise training in older adults, particularly in a group of older men and women, who may benefit from increases in muscle mass, muscle strength, and physical function to improve functional performance and health-related quality of life. However, the present study also highlights the importance of a longer duration of resistance-type exercise training, as the observed improvements were not consistent across all individuals. Further research is needed to determine the optimal duration and intensity of resistance-type exercise training for older adults to maximize the benefits of improved muscle mass, muscle strength, and physical function.
Fig. 1. Histograms of the absolute changes in lean body mass (kg) for each individual after 12 (A) and 24 (B) weeks of resistance-type exercise training in elderly men and women. Numbers next to the bars represent the individual participants and match with the same participant number presented in Figures 1–6.
of health outcomes. In the present study, we observed increases in lean body mass of 0.9 \pm 0.1 \text{ kg} (1.8\% \pm 0.3\%) and 1.1 \pm 0.2 \text{ kg} (2.3\% \pm 0.4\%) after 12 and 24 weeks of training, respectively. The changes in lean body mass were highly variable between participants, with measured changes ranging from \(-3.3\) (participant 75) to \(+5.4\) kg (participant 63) after 12 weeks, to \(-1.8\) (participant 75) and \(+9.2\) kg (participant 69) after 24 weeks of exercise training (Figure 1A and B). Participant 75, who demonstrated the lowest change in lean body mass

Fig. 2. Histograms of the absolute changes in type I muscle fiber cross-sectional area (\text{\mu m}^2) for each individual after 12 (A) and 24 (B) weeks of resistance-type exercise training in elderly men and women. Numbers next to the bars represent the individual participants and match with the same participant number presented in Figures 1-6.
in response to training at both 12 and 24 weeks, showed positive increases in both type I and II fiber size and 1-RM strength, and an improvement in chair-rise time from 0–12 weeks. The precision of DXA for whole-body lean soft tissue expressed as CV ranges from 0.4% to 1.3% (SEM 0.35–0.54 kg) in sequential measurements, and it is difficult to assess whether reported changes on an individual level are representative of the actual changes in body mass in the individual. For this reason, relatively large groups of individuals are generally included to
Fig. 4. Histograms of the absolute changes in 1-RM on the leg press (kg) for each individual after 12 (A) and 24 (B) weeks of resistance-type exercise training in elderly men and women. Numbers next to the bars represent the individual participants and match with the same participant number presented in Figures 1–6.
Fig. 5. Histograms of the absolute changes in 1-RM on the leg extension (kg) for each individual after 12 (A) and 24 (B) weeks of resistance-type exercise training in elderly men and women. Numbers next to the bars represent the individual participants and match with the same participant number presented in Figures 1–6.
Fig. 6. Histograms of the absolute changes in chair-rise time (seconds) for each individual after 12 (A) and 24 (B) weeks of resistance-type exercise training in elderly men and women. Numbers next to the bars represent the individual participants and match with the same participant number presented in Figures 1–6.
assess the efficacy of a given exercise intervention to increase lean body mass.26 However, the present analyses revealed that 23 participants (~21%) and 16 participants (~19%) failed to show a measurable increase in lean body mass after 12 and 24 weeks of resistance-type exercise training (Figure 1A and B). Despite 23 participants not demonstrating a measurable increase in lean body mass from 0 to 12 weeks, 9 of these participants (participants 36, 38, 18, 9, 82, 74, 79, 28, 6) demonstrated a positive increase in lean body mass from 0 to 24 weeks (Figure 1A and B).

In agreement with previous studies demonstrating that even the very old maintain the capacity to augment muscle fiber size in response to resistance-type exercise training,24,25 type I fiber CSA increased by 8% ± 3% and 9% ± 3% after 12 and 24 weeks of resistance-type training, respectively. Similarly, type II fiber CSA increased by 17% ± 3% and 23% ± 4% after 12 and 24 weeks of training. Despite such large average increases in type I and II fiber size, there was substantial heterogeneity in the individual changes. For example, changes in type I and II muscle fiber size ranged from −4458 (participant 53) and −4041 (participant 55) μm² to +3386 (participant 55) and +3904 (participant 88) μm² from 0 to 12 weeks of training (Figure 2A and 3A; Tables 2 and 3). The present analyses revealed that 36 participants (~39%) and 22 participants (~33%) did not show an increase in type I muscle fiber size, whereas we failed to detect a measurable increase in type II muscle fiber size in 25 participants (~27%) and 17 participants (~26%) after 12 and 24 weeks of training (Figure 2–3). Despite the relatively large number of participants who did not show measurable increases in muscle fiber size, every one of these participants demonstrated substantial increases in 1-RM leg strength, possibly implying improved neurological function in response to training.26

Consistent with previous work,6–16 resistance-type exercise training resulted in substantial increases in muscle strength (Figures 4 and 5). Leg press 1-RM increased by 23% ± 2% and 35% ± 2% after 12 and 24 weeks of training. Similar observations were observed for the leg extension (28% ± 2% and 42% ± 2%, respectively). Although there was substantial interindividual variability in the changes in 1-RM leg strength, only 2 participants failed to demonstrate measurable increases in 1-RM leg press (participants 85 and 26) and leg extension (participants 85 and 79) strength after 12 weeks of training. Similarly, only a single participant (participant 85) did not show an increase in leg strength after 24 weeks of training. Of interest, this participant (participant 85) demonstrated the greatest improvements in chair-rise time ability at both 12 and 24 weeks after training. Substantial improvements in physical function were also observed, with a large 8.2% ± 2.5% and 17.8% ± 1.9% reduction in the time required for the chair-rise test after 12 and 24 weeks of training. Twenty two participants (26%) failed to show improvement on the chair-rise time test after 12 weeks of training. After 24 weeks, only 5 participants (6%) showed no improvement compared with baseline values (Figure 6). This observation demonstrates that being nonresponsive after 12 weeks of training certainly is not predictive on the outcome after a more prolonged training intervention.

In the present study, we present the individual changes in lean body mass, type I and II muscle fiber size, leg strength, and physical function in a large group of older men and women. There was quite some variance in the changes in lean body mass, muscle fiber size, strength, and function between individuals. This is in line with the established heterogeneity in the adaptive response to training.7–9 and this may be further augmented by the differences between subjects regarding the level of frailty, nutritional status, protein supplementation, and training regimen within the included cohorts.16–18,22 Some individuals seemed to show no or even an apparent negative response on one of the outcome parameters (Figures 1–6) and could, therefore, be referred to as “nonresponders” or “adverse responders.”13 However, a critical evaluation of the individual data demonstrates that participants who seemed unresponsive with regard to, for example, an increase in lean body mass after 12 (participants 74, 94, 5, 61, 85, 2, 36, 88, 3, 56, 70, 109, 38, 18, 108, 9, 53, 82, 74, 55, 79, 28, and 6) or 24 (participants 75, 5, 53, 2, 57, 61, 11, 55, 70, 3, 81, 85, 56, 17, 77, and 66) weeks of exercise training, were all highly responsive to one or more of the other training outcomes. In fact, only 2 of 110 participants (2%) failed to show improvements in 1-RM leg strength after 12 weeks of training. Our findings appear to agree with the suggestion that the intercorrelation between being unresponsive to training on one physiological trait and another is very low (~ρ = 0.1–0.05).28 Thus, lack of improvement on one specific phenotype (ie, lean body mass or muscle fiber size) is not a reason not to recommend or prescribe resistance-type exercise training because substantial improvements in another phenotype (strength and/or physical function) can still be obtained. Furthermore, there was a decline in the number of people deemed unresponsive when comparing responses after 12 and 24 weeks of training. In other words, being nonresponsive to the impact of 12 weeks of exercise training on a certain parameter does not preclude a normal adaptive response observed after more prolonged intervention. Consequently, our data do not provide any sign of the existence of nonresponsiveness to the benefits of resistance-type exercise training. Moreover, we feel it is a misconception to assume that a few single measurements in time provide realistic insight in the absolute changes in a certain physiological trait within a single individual. There is a reason why groups of individuals are included in clinical studies and why statistical tests are used to test research hypotheses. The present data set shows that conclusions based on an n = 1 can be quite deceiving. The important work of many of our colleagues addressing the basis of the observed heterogeneity in the adaptive response to exercise interventions17–19,29–32 is often misinterpreted by the popular media, suggesting that a substantial part of the population does not benefit from an exercise intervention.

Conclusions

The present data show that there is no rationale to assume that there is such a thing as unresponsiveness to the benefits of exercise training and, as such, we should not be restrictive in the prescription of resistance-type exercise training to augment lean body mass, muscle fiber size, muscle strength, and physical function in the older population. Even in situations in which an individual demonstrates what might be classified as an adverse response to exercise13 on a single outcome measure, that response needs to be carefully weighed against the myriad of health benefits derived from regular exercise training. Of course, we can only speculate on the relative contribution of musculoskeletal, neurological, or behavioral adaptation on the reported increases in muscle mass, strength, and function in the older population. In conclusion, there are no nonresponders to the benefits of resistance-type exercise training on lean body mass, muscle fiber size, muscle strength, or function in the older population. Resistance-type exercise should be promoted to support healthy aging in the older population.

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Supplementary Data

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.jamda.2015.01.071.
References


