Influence of combined resistance training and healthy diet on muscle mass in healthy elderly women: a randomized controlled trial

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Submitted 23 January 2015; accepted in final form 20 August 2015


BETWEEN 2000 AND 2050, the proportion of the world’s population over 60 years of age is projected to double from 11 to 22%, increasing from 605 million to 2 billion (66). In parallel, despite the fact that the risk of having a disability accelerates after the age of 80, the current and future older population may spend more years healthy and disability-free than past populations aged 65 and older (33, 34). These demographic changes imply that research aiming to improve health in the older population should focus on subjects with deteriorated health as well as healthy older adults.

Aging is accompanied with a progressive decline in skeletal muscle mass leading to sarcopenia. The loss of muscle mass occurs together with a decline in muscle strength and power (19), especially in lower limb muscles (36). Low-grade chronic systemic inflammation, which is defined as a minor elevation in the baseline levels of acute-phase proteins and cytokines (10), is currently considered as an important factor contributing to the age-related functional decline. In this respect, C-reactive protein (CRP), one of the most frequently used markers of systemic inflammation, has been shown to be elevated in older adults (15). Elevated concentrations of CRP have been found to be associated to many age-related adverse changes (7, 39), and even older adults with CRP levels ≥1.2 mg/l have a moderately increased risk of developing disease (45), highlighting the role of low-grade systemic inflammation in the age-related functional decline. Although elevations in systemic markers of inflammation have not been reported in all studies (4), the reduction in muscle mass and strength has been found to be associated with increases in systemic markers of inflammation in older adults (51). It has also been shown that the systemic inflammation can blunt the postprandial muscle protein synthesis in aged rats (1). Interestingly, the administration of anti-inflammatory drugs can restore muscle protein synthesis in old rats (46). Additionally, it has been shown that a treatment with anti-inflammatory drugs together with resistance training has beneficial effects on muscle volume and strength (57). Though an anti-inflammatory medication might prove beneficial, daily administration of anti-inflammatory drugs is currently not feasible, indicating the need to develop efficient nonpharmacological approaches to maintain muscle function in healthy older adults.

Resistance training is currently considered as the most efficient nonpharmacological strategy to counteract the age-related loss of muscle mass in older adults (41). However, several studies included physically inactive participants as well as older adults with chronic diseases or frail people. In healthy old men and women, resistance training-induced increases in muscle mass have been reported in some (2, 22, 30) but not in all studies (27, 60). Moreover, gains in muscle mass have been reported in older men but not in women (20). There are also discrepancies among studies addressing the efficiency of long-term resistance training in reducing the systemic inflammatory level. Resistance training-induced reductions in systemic markers of inflammation have been reported in older and middle-aged inactive individuals with risk factors for chronic diseases and relatively elevated baseline serum inflammatory markers in some (42) but not in all studies (9). The ability of dietary approaches to reduce systemic inflammation has also been considered. The polyunsaturated omega-3 (n-3) fatty acids have been suggested to have anti-inflammatory properties (14), as a significant decrease in the level of the pro-inflammatory precursor arachidonic acid (AA) has been reported in healthy middle-aged subjects supplemented with the n-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (16, 26). It has been shown that higher concentrations

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of AA are associated with smaller muscle size (44), and AA has been shown to be an important signaling event in the induction of muscle protein degradation through an increased expression and activity of the ubiquitin-proteasome pathway (65). On the contrary, n-3 fatty acids have been shown to inhibit protein degradation (62) and reduce the normal decline in muscle mass and function in older adults (55). Furthermore, supplementation with n-3 fatty acids increases muscle protein synthesis above basal, postabsorptive values in older adults (54). Altogether, alterations in serum levels of n-3 fatty acids might have a direct action on muscle mass in older adults. To our knowledge, there is no data on the effects of resistance training combined with a whole diet approach aiming to modify the n-6/n-3 ratio on muscle mass in healthy, physically active older women.

By using a three-armed randomized controlled trial, the objective of this investigation was to evaluate the effects of 6 mo of resistance training combined with a healthy diet on skeletal muscle mass and strength as well as systemic markers of inflammation in a population of healthy, physically active older women.

MATERIALS AND METHODS

Study design. A three-armed randomized controlled trial was performed. Randomization was done by block design to ensure equal numbers of older women assigned to a control group (CON; 68 ± 1 yr), a resistance training group (RT; 68 ± 2 yr) and a resistance training plus healthy diet group (RT-HD; 67 ± 1 yr). To ensure that the comparison groups were as similar as possible with regard to baseline inflammatory level, the randomization was stratified by serum CRP level. All subjects were informed about the nature and possible risks of the experimental procedures before written, informed consent was obtained. The study was conducted in accordance with the policy statement set forth in the Declaration of Helsinki and approved by the regional ethical review board of Uppsala.

Subjects. Elderly women were recruited through an advertisement in a local newspaper. A medical history and electrocardiograms were assessed by a physician. Exclusion criteria were 1) living in a nursing home; 2) self-reported inability to walk; 3) cardiovascular, pulmonary, metabolic, rheumatologic, and psychiatric disease; 4) musculoskeletal problems; 5) use of medication; 6) a food allergy; and 7) unexplained weight loss, defined as unintended loss ≥ 5% body wt over the preceding 6–12 mo. To be included in the study, older women had to be aged between 65 and 70 years, with a BMI < 30, fasting glucose < 6 mmol/l, fasting cholesterol < 8 mmol/l, systolic blood pressure < 140 mmHg, and diastolic blood pressure < 90. Additionally, subjects had to be recreationally physically active. The subjects physical activity behaviors were assessed by a previously validated questionnaire (EPAQ2) (63). All subjects included in the study participated in various recreational physical activities, such as walking, Nordic walking, jogging, cycling, swimming, and skiing; none of the subjects had previously participated in structured resistance training. In total, 122 volunteers were screened and the 63 older women who remained after applying inclusion and exclusion criteria were considered eligible for the randomized controlled trial (RCT). After the 63 women were randomized into three groups, a total of eight subjects withdrew from the study (3 from CON, 4 from RT, and 1 from RT-HD) and did so for reasons not related to the intervention (Fig. 1). The CON group was asked to maintain their normal activities of daily living.

Resistance training intervention. Supervised progressive resistance training was performed twice a week during 24 wk. Subjects performed three sets per exercise with 2 min of rest between sets and 3 min of rest between exercises. The initial workload corresponded to 50% of 1 repetition maximum (1 RM) during the first 2 wk where the subjects performed 12–15 repetitions per set. A workload of 75–85% 1 RM (8–12 reps/set) was set for the rest of the intervention. Training load was adjusted throughout the intervention. The following exercises were performed: squat, leg extension, leg press, seated row, and pull down. Additionally, 5 min of core stability exercises and seven squat jumps were included. Training sessions ended with 5 min of stretching exercises.

Diet and dietary assessment. The subjects in the RT-HD group attended a dietary consultation and were given a diet plan. Details of the prescribed diet are summarized in Table 1. Briefly, 44 E% of carbohydrates (fiber intake >25 g/day), 36 E% of fat (mainly monounsaturated and polyunsaturated fatty acids), and 20 E% of protein with the following major adjustment: the n-6/n-3 ratio <2. In accordance with these general dietary goals, several numbered menus were proposed to the participants. The subjects were trained to prepare their meals according to the recommendations provided by a nutritionist. The daily calorie requirements for each participant in RT-HD were calculated based on predicted basal metabolic rate (BMR) by the Harris-Benedict equation (50) and estimated physical activity level. The dietary intake was adjusted in 200 kcal increments to match individual energy requirements. Subjects in CON and RT were instructed to maintain their habitual dietary intake throughout the study. The dietary intake was monitored by using a food record over a period of 6 days at baseline, week 12, and week 24. The subjects were instructed by a nutritionist on how to record their daily food intake by

Fig. 1. Organization chart of participant flow throughout the study.
Table 1. Nutrient goals and prescribed key foods for the dietary intervention

<table>
<thead>
<tr>
<th>Nutrient goals</th>
<th>Dietary Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate, E%</td>
<td>44</td>
</tr>
<tr>
<td>Fiber, g/day</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Protein, E%</td>
<td>20</td>
</tr>
<tr>
<td>Total fat, E%</td>
<td>36</td>
</tr>
<tr>
<td>Saturated fat, E%</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Unsaturated fat</td>
<td>2/3 of total fat</td>
</tr>
<tr>
<td>n-6/n-3 ratio</td>
<td>&lt;2</td>
</tr>
</tbody>
</table>

Prescribed foods

<table>
<thead>
<tr>
<th>Cereal products</th>
<th>High whole-grain (rye, oat, barley)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables/fruit/berries</td>
<td>≥600 g/day</td>
</tr>
<tr>
<td>Fish and seafood</td>
<td>≥500 g/wk</td>
</tr>
<tr>
<td>Dietary fats</td>
<td>Rape seed oil, olive oil, nuts and seeds</td>
</tr>
<tr>
<td>Meat products</td>
<td>Lean meat</td>
</tr>
<tr>
<td>Dairy products</td>
<td>≥0.5 l/day (low fat)</td>
</tr>
<tr>
<td>Soft drinks/juice</td>
<td>Be avoided/P&lt;1.5 dl juice/day</td>
</tr>
</tbody>
</table>

E%, energy percent.

results

At baseline there were no significant differences between groups with regard to age, BMI, leg lean mass, leg fat mass, leg bone mineral density (BMD), strength, CRP, IL-6 (Table 2). There were no significant alterations in BMI by the end of the 24-wk intervention in any of the groups. Training attendance for the participants was 87 ± 8% (39 ± 4 sessions, 1.77 ± 0.15 sessions/wk) and 91 ± 6% (41 ± 3 sessions, 1.81 ± 0.13 sessions/wk) in the RT and RT-HD groups, respectively. The assessment of physical activity level at baseline revealed that all participants met the physical activity recommendation of accumulating 30 min or more of moderate-to-vigorous physical activity per day on 5 or more days/wk (23). We also found that the level of physical activity was similar between the groups at baseline (Table 2) and that there were no significant changes in the activity level over the 24-wk intervention period (Table 2), the latter indicating that participants did not modify their physical activity behaviors during the study.
Table 2. Body composition, physical activity level, serum inflammatory markers and muscle strength at baseline and by the end of the study

<table>
<thead>
<tr>
<th>Variable</th>
<th>CON, n = 21</th>
<th>POST, n = 18</th>
<th>RT, n = 21</th>
<th>POST, n = 17</th>
<th>RT-HD, n = 20</th>
<th>POST, n = 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, cm</td>
<td>165 ± 4.6</td>
<td>163 ± 5.3</td>
<td>165 ± 5.3</td>
<td>165 ± 5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass, kg</td>
<td>67.1 ± 8.2</td>
<td>65.2 ± 8.0</td>
<td>65.8 ± 8.2</td>
<td>65.9 ± 11.0</td>
<td>65.7 ± 10.9</td>
<td></td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.3 ± 5.8</td>
<td>24.5 ± 2.8</td>
<td>24.6 ± 2.9</td>
<td>24.3 ± 3.9</td>
<td>24.4 ± 4.6</td>
<td></td>
</tr>
<tr>
<td>1 RM leg extension</td>
<td>49.7 ± 9.6</td>
<td>49.2 ± 10.2</td>
<td>59.0 ± 10.3</td>
<td>49.5 ± 6.3</td>
<td>60.0 ± 7.1*</td>
<td></td>
</tr>
<tr>
<td>CRP, mg/l</td>
<td>1.9 ± 0.93</td>
<td>1.25 ± 0.78</td>
<td>1.33 ± 0.76</td>
<td>1.35 ± 0.89</td>
<td>1.46 ± 1.06</td>
<td></td>
</tr>
<tr>
<td>IL-6, pg/l</td>
<td>1.85 ± 1.77</td>
<td>1.29 ± 0.92</td>
<td>1.27 ± 1.05</td>
<td>1.22 ± 0.90</td>
<td>1.44 ± 1.12</td>
<td></td>
</tr>
<tr>
<td>Leg lean mass, kg</td>
<td>12.6 ± 1.66</td>
<td>12.78 ± 1.28</td>
<td>12.82 ± 1.43</td>
<td>12.50 ± 1.58</td>
<td>12.71 ± 1.53*</td>
<td></td>
</tr>
<tr>
<td>Leg fat mass, kg</td>
<td>8.34 ± 1.94</td>
<td>8.53 ± 1.85</td>
<td>8.72 ± 1.99</td>
<td>9.17 ± 3.43</td>
<td>8.99 ± 3.18</td>
<td></td>
</tr>
<tr>
<td>Leg BMD, g/cm²</td>
<td>1.15 ± 0.11</td>
<td>1.13 ± 0.08</td>
<td>1.12 ± 0.08</td>
<td>1.14 ± 0.10</td>
<td>1.15 ± 0.09</td>
<td></td>
</tr>
<tr>
<td>PA, cnts-min -1·day⁻¹</td>
<td>278 ± 151</td>
<td>268 ± 62</td>
<td>257 ± 49</td>
<td>337 ± 127</td>
<td>329 ± 174</td>
<td></td>
</tr>
</tbody>
</table>

All values are given as means ± SD. *P ≤ 0.05. CON, control group; RT, resistance training group; RT-HD, resistance training + healthy diet group; CRP, C-reactive protein; BMI, body mass index; RM, repetition maximum; BMD, bone mineral density; PA, physical activity.

The assessment of the dietary intake showed no significant differences in macronutrients intake between the three groups at baseline and revealed that participants in CON and RT did not alter their nutritional habits throughout the study period (Table 3). In accordance with the dietary goals, dietary n-3 polyunsaturated fatty acids (PUFA) increased as expected, and consequently the n-6/n-3 ratio dietary intake significantly decreased only in RT-HD by 42% (from 3.1 ± 1.3 to 1.8 ± 0.6, P < 0.05).

Stratification by CRP ensured equal baseline inflammatory status in the three groups (Table 2). The baseline levels of both CRP and IL-6 in this population of healthy older women were low and were not altered in response to the intervention. The analysis of blood samples showed that there was a significant increase in n-3 DHA serum level (+5.1%) in RT-HD only, which further confirms dietary compliance. There were no significant changes in serum fatty acids α-linolenic acid, EPA and linoleic acid in any of the groups in response to the intervention (Table 4). Interestingly, despite the low inflammatory level of participants, there was a significant decrease in the pro-inflammatory precursor AA in RT-HD only (−5.3 ± 9.4%, P < 0.05) (Table 4).

The training volume in leg extension exercise was similar for both training groups (1,183 ± 219 kg/session in RT and 1,186 ± 143 kg/session in RT-HD, P = 0.962). By the end of the intervention period, there was a significant increase in 1 RM in leg extension in both RT and RT-HD (Fig. 2A). Maximal isometric quadriceps strength also increased significantly (P < 0.05) in both RT (19.0 ± 3.4%) and RT-HD (15.3 ± 3.5%). On the contrary, CON did not change their 1 RM in leg extension over the course of the 24-wk period (−1.9 ± 6.4%, P = 0.278) (Fig. 2A). Leg lean mass, fat mass, and BMD evaluated by using DXA revealed no significant differences between the three groups at baseline (Table 2). However, there was a significant increase in leg lean mass in response to the 24-wk intervention only in RT-HD (time × group effect, P = 0.027) (Fig. 2B). ANCOVA was used to control for possible confounding effects of total energy intake and absolute or relative protein intake on changes in muscle mass. We found that these covariates had no significant effects on changes seen by the end of the intervention.

DISCUSSION

The present study provides information on the combined effects of exercise and dietary interventions in a group of recreationally active older women homogenous with respect to age and with no chronic diseases. The main findings of the present study were that resistance training improves muscle strength in healthy and recreationally active older women and that gains in skeletal muscle mass occur only when resistance training is combined with a healthy diet.

In our study, the design of the diet was based on a whole dietary approach with no use of dietary supplements or pharmacological agents. The prescribed diet was in line with the current dietary guidelines in Europe and the United States, i.e., a healthy diet rich in wholegrain products, vegetables, fruits, fish, and polyunsaturated fats from vegetable oils and nuts.
oxidative stress in subjects with low-grade systemic inflammation does not increase signs of inflammation or result in a 3-fold increase in the n-6/n-3 PUFA ratio, even in feeding trials, even a dramatic increase in n-6 PUFA intake was not associated with elevated systemic inflammation. In older adults, although higher intakes of n-6 PUFA were generally reported in response to resistance training, improvements in leg lean mass were not accompanied by changes in serum inflammatory markers. Reductions in serum CRP and IL-6 levels were low and the diet-induced improvement of muscle mass without changes in serum inflammatory levels was consistent with the hypothesis that physical exercise acts predominantly by reducing body fat. This is supported by the fact that resistance training improves muscle strength in both RT and RT-HD in accordance with several studies in both healthy and frail older adults. However, our findings show that resistance training alone did not lead to significant improvements in leg lean mass in a population of healthy and physically active older women. Likewise, previous reports failed to show any significant improvements in muscle mass in older men and women, and one report demonstrated significant resistance training-induced improvements in muscle mass in older men but not in women. As indicated earlier, the time spent in moderate-to-vigorous physical activity by the participants in this study was in line with the recommendations for physical activity in both young and older adults and higher than what has been reported in previous studies assessing physical activity behaviors in older women. In this respect, improvements of muscle mass are more frequently reported in physically inactive older and old/frail subjects with risk factors for chronic diseases. Even in frail older people, it has recently been demonstrated that a dietary protein supplementation is required to increase muscle mass.

A previous study demonstrated that administration of over-the-counter dosages of nonsteroidal anti-inflammatory drugs combined with a resistance training program appeared to enhance muscle hypertrophy and strength gains compared with resistance training alone in older adults. The significant improvements in leg lean mass in our healthy, physically active older women occurred only when resistance training was combined with the healthy diet. In this population of healthy and physically active older women, baseline serum CRP and IL-6 levels were low and the diet-induced improvement of muscle mass was not accompanied by changes in serum levels of these markers. Several previous investigations exploring the effects of whole diet (58), supplementation with fish oil (43), or resistance training alone (9) did not report changes in systemic inflammatory markers. Reductions in serum CRP and IL-6 levels were generally reported in response to resistance training in older adults with low physical activity levels and were accompanied by a decrease in fat mass in some but not all studies (37). It has also been shown that supplementation with the n-3 ω-linolenic acid reduces IL-6 levels in older men but not in women (11) and that even increased n-6 PUFA intake is not associated to elevated systemic inflammation (21). In feeding trials, even a dramatic increase (>3-fold) in the n-6/n-3 PUFA ratio does not increase signs of inflammation or oxidative stress in subjects with low-grade systemic inflammation (i.e., metabolic syndrome or Type 2 diabetes) (6). Moreover, it was recently shown that compared with a diet with low intake in n-6 PUFA and high in saturated fatty acids, a diet with high intake in n-6 PUFA induced an increase in total muscle mass without changes in serum inflammatory levels (48). Alternatively, changes in baseline serum CRP levels occur only under the influence of the cumulative effects of exercise and dietary changes over the course of many years, and not after shorter-term interventions. This possibility is consistent with the hypothesis that physical exercise acts predominantly by reducing body fat. This is supported by the Table 4. Fatty acid composition in phospholipids at baseline and by the end of the study

<table>
<thead>
<tr>
<th>Variable</th>
<th>CON, n = 14</th>
<th>RT, n = 17</th>
<th>RT-HD, n = 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>18:3 n-3, %</td>
<td>0.27 ± 0.10</td>
<td>0.29 ± 0.06</td>
<td>0.29 ± 0.06</td>
</tr>
<tr>
<td>20:5 n-3, %</td>
<td>2.30 ± 0.79</td>
<td>2.37 ± 0.62</td>
<td>2.77 ± 0.97</td>
</tr>
<tr>
<td>22:6 n-3, %</td>
<td>5.80 ± 1.16</td>
<td>6.10 ± 1.30</td>
<td>5.73 ± 0.91</td>
</tr>
<tr>
<td>18:2 n-6, %</td>
<td>19.81 ± 2.05</td>
<td>19.66 ± 2.52</td>
<td>20.84 ± 1.23</td>
</tr>
<tr>
<td>20:4 n-6, %</td>
<td>8.91 ± 1.77</td>
<td>8.57 ± 1.73</td>
<td>8.18 ± 1.30</td>
</tr>
</tbody>
</table>

All values are given as means ± SD. *Indicates significant changes compared with PRE, P ≤ 0.05. Variable 18:3 n-3, α-linolenic acid; 20:5 n-3, eicosapentaenoic acid; 22:6 n-3, docosahexaenoic acid; 18:2 n-6, linoleic acid; 20:4 n-6: arachidonic acid.
association between weight loss and reductions in CRP levels (52).

The increase in muscle mass, which occurred only in RT-HD, was accompanied by a diet-induced reduction of AA and an increase in DHA. Decreased AA might have a positive effect on muscle mass, as it has been shown that higher concentrations of AA are associated with smaller muscle size (44). Additionally, AA has been shown to be an important signaling event in the induction of muscle protein degradation through an increased expression and activity of the ubiquitin-proteasome pathway (65). Additionally, the diet-induced increase in serum n-3 DHA might have contributed to the increase in muscle mass as n-3 fatty acids have been shown to inhibit protein degradation (62), enhance muscle protein synthesis (54), and reduce the normal decline in muscle mass and function in older adults (55). Despite the fact that leg lean mass increased significantly in RT-HD, there were no significant differences in the magnitude of the improvement in leg extension strength between RT and RT-HD. This implies that significant changes in muscle strength can be achieved without significant changes in muscle mass in older women, highlighting the role of neuromuscular adaptations (i.e., motor unit recruitment) in strength improvements in older adults. It can thus be hypothesized that the 1.8% improvement in leg lean mass in RT-HD does not necessarily translate into superior effects on muscle strength in healthy and physically active older women. In older women, previous studies showed significant increases in muscle strength with no significant increases in skeletal muscle mass after resistance training (20, 27, 60), and in studies reporting increases in skeletal muscle mass in healthy older adults, the magnitude of changes generally ranges between 2 and 6% (2, 18, 22, 24, 30, 49, 53, 59). Sillanpaa et al. (2009) reported a 2% increase in lean leg mass following 21 wk of resistance training in older women aged between 39 and 64 yeras (53). Leenders et al. (2013) also reported a 2.9% increase in leg lean mass in healthy older women following 6 mo of resistance training (30). A 2.1% increase in fat-free mass was reported after 6 mo of resistance training in participants who underwent a period of 8 mo of detraining prior to the start of the intervention (49). Differences in the physical activity level of participants prior to the intervention and individual differences in the response to exercise might explain the differences between the studies. In general, the low magnitude of training-induced changes in muscle mass in older women can also be explained by a reduction of the anabolic response to exercise in older individuals (28).

The 24-wk dietary intervention was self-administered and based on dietary counseling. This dietary design is less rigorous than controlled nutrient diets. However, the strategy used in our study allows reducing the participant burden given that one of the major challenges in any long-term dietary study is the retention of eligible study members for the duration of the intervention. To improve participant compliance, several menus were designed according to the general dietary goals. Food records performed at the start, in the middle, and at the end of the intervention indicated high compliance. Furthermore, the increase in the n-3 fatty acid DHA serum level, which occurred only in RT-HD, further points to a high level of compliance. By the end of the intervention, there was a nonsignificant mean difference of 186 kcal/day in RT-HD. This slight difference in total energy intake and in absolute or relative protein intake had no significant influence on changes in muscle mass. Noteworthy, previous studies showed that protein intakes of 0.9 g·kg⁻¹·day⁻¹ or 1.2 g·kg⁻¹·day⁻¹ combined with resistance training gave similar effects on muscle mass in older adults, indicating that increases in protein intake in subjects with already adequate protein intake would not further enhance the effects of the intervention (25). Participants included in our study had a baseline protein intake of ~1 g·kg⁻¹·day⁻¹, which is considered an adequate intake for older women (3, 12, 47). In the present study, body composition was assessed by using DXA, which is less accurate than other tools such as computed tomography (CT) or magnetic resonance imaging (MRI). DXA has previously been considered to be a reasonable alternative to CT and MRI for estimating regional and total body composition (29), and by using DXA the amount of radiation is far less than other methods. Furthermore, it has been demonstrated that the use of DXA for the regional analysis of the limb area is particularly accurate compared with DXA measurement of the trunk area (64). Additionally, previous studies have evaluated body composition by using DXA, CT, and MRI and showed good between-method agreement in the determination of muscle size (17, 32, 61).

Our findings suggest that the practice of resistance training together with the adoption of a healthy diet by a population of healthy and physically active older women with no risk factors for chronic diseases and low serum levels of inflammatory markers can optimize the resistance training-induced gains in muscle mass. To reduce the prevalence of sarcopenia and to delay the age-related functional decline, it is important to evaluate the myogenic potential of nonpharmacological interventions before the occurrence of different comorbidities leading to muscle weakness. In this study, although moderate, the intervention-induced changes in muscle mass can be considered to be promising as they can be implemented in healthy active older women and can delay the impact of aging on the muscular system. It can also be hypothesized that the same intervention would induce more benefits at the level of muscle mass in inactive older women with poor health status. Further research is needed to understand the molecular mechanisms underlying changes in muscle mass in response to combined resistance training and a healthy diet.

In conclusion, an intervention based on resistance training combined with a healthy diet can optimize the resistance training-induced increases in skeletal muscle mass in healthy and physically active older women. Increases in muscle mass were not accompanied by a reduction of serum CRP or IL-6 but were associated with a diet-induced reduction in serum AA and an increase in serum DHA. This information is important for refining cointerventions compatible with long-term lifestyle changes aiming to improve muscle mass in older women in order to delay the occurrence of sarcopenia.

ACKNOWLEDGMENTS

We thank the participants as well as Rolf Pettersson, Per Odenkrans, Adrian Hosford-Donovan, Sara Mijwel, Sofia Nilsson, Jenny Ewen, and Siv Tengblad for their help during the study.

GRANTS

Support for this study was provided by Swedish National Center for Research in Sports Grants P2012/0102 and P2014-0117.
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