Protein Supplementation Increases Muscle Mass Gain During Prolonged Resistance-Type Exercise Training in Frail Elderly People: A Randomized, Double-Blind, Placebo-Controlled Trial

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Keywords: Sarcopenia, aging, frailty, hypertrophy, muscle strength

Objectives: Protein supplementation has been proposed as an effective dietary strategy to augment the skeletal muscle adaptive response to prolonged resistance-type exercise training in elderly people. Our objective was to assess the impact of protein supplementation on muscle mass, strength, and physical performance during prolonged resistance-type exercise training in frail elderly men and women.

Design/setting/participants: A randomized, double-blind, placebo-controlled trial with 2 arms in parallel among 62 frail elderly subjects (78 ± 1 year). These elderly subjects participated in a progressive resistance-type exercise training program (2 sessions per week for 24 weeks) during which they were supplemented twice daily with either protein (2 * 15 g) or a placebo.

Measurements: Lean body mass (DXA), strength (1-RM), and physical performance (SPPB) were assessed at baseline, and after 12 and 24 weeks of intervention.

Results: Lean body mass increased from 47.2 kg (95% CI, 43.5–50.9) to 48.5 kg (95% CI, 44.8–52.1) in the protein group and did not change in the placebo group (from 45.7 kg, 95% CI, 42.1–49.2 to 45.4 kg, 95% CI, 41.8–48.9) following the intervention (P value for treatment * time interaction = .006). Strength and physical performance improved significantly in both groups (P = .000) with no interaction effect of dietary protein supplementation.

Conclusions: Prolonged resistance-type exercise training represents an effective strategy to improve strength and physical performance in frail elderly people. Dietary protein supplementation is required to allow muscle mass gain during exercise training in frail elderly people.

Trial Registration: clinicaltrials.gov identifier: NCT01110369.
performance in frail elders.\textsuperscript{27,28} We hypothesized that dietary protein supplementation is needed to increase muscle mass, strength, and physical performance during prolonged resistance-type exercise training in frail elderly people. Therefore, 62 frail elderly men and women were selected to participate in a 24-week supervised resistance-type exercise training program during which they were supplemented with or without additional dietary protein (2\textsuperscript{15} g daily) in a randomized, double-blind, placebo-controlled, manner.

**Methods**

**Subjects**

Elderly subjects (≥65 years old) were recruited from an existing database, through distribution of flyers, and by local information meetings between December 2009 and September 2010. Potentially eligible elderly people were screened for prefrailty and frailty using the Fried criteria.\textsuperscript{2} These criteria are (1) unintentional weight loss, (2) weakness, (3) self-reported exhaustion, (4) slow walking speed, and (5) low physical activity. Prefrailty was classified when 1 or 2 criteria were present and frailty was defined when 3 or more criteria were present. Medical history of all subjects was evaluated. Subjects who were diagnosed with cancer, chronic obstructive pulmonary disease, or muscle disease or who were unable to perform the exercise regimen were excluded. Subjects with type 2 diabetes (≥7 mmol/L)\textsuperscript{29} and renal insufficiency (eGFR <60 mL/min/1.73 m\textsuperscript{2})\textsuperscript{30} were excluded. A resting electrocardiogram was performed to exclude silent ischemia. The Wageningen University Medical Ethical Committee approved the study and subjects gave their written informed consent.

**Study Design**

After inclusion, subjects were randomly allocated to either protein or placebo supplementation. Both groups were included in a 24-week resistance-type exercise training program. An independent person randomized subjects by means of computer-generated random numbers in stratified permuted blocks of size 4, stratified by gender. Primary outcome measure was lean body mass measured by dual-energy \(\times\)-ray absorptiometry (DXA). Secondary outcome measures included maximum strength (1 repetition maximum [1-RM], handgrip strength) and physical performance (short physical performance battery [SPPB]). In addition, blood samples were collected to determine plasma glucose and insulin concentrations and markers for renal functional decline. Furthermore, 3-day food records were collected to define habitual dietary intake. All measures were collected before and after 12 and 24 weeks of intervention.

**Resistance-Type Exercise Training Program**

The resistance-type exercise training was performed 2 times per week under personal supervision for a 24-week period. The sessions were performed in the morning and afternoon with at least 72 hours between sessions. The training consisted of a 5-minute warm-up on a cycle ergometer, followed by 4 sets on the leg-press and leg-extension machines and 3 sets on chest press, lat pulldown, pec-dec, and vertical row machines (Technogym, Rotterdam, the Netherlands). The workload started at 50\% of 1-RM (10–15 repetitions per set) and was increased to 75\% of 1-RM (8–10 repetitions) to stimulate muscle hypertrophy. Resting periods of 1 minute were allowed between sets and 2 minutes between exercises. To evaluate changes in muscle strength, 1-RM was repeated after 4, 8, 12, 16, and 20 weeks of training. Workload intensity was adjusted based on the 1-RM outcomes.

**Protein Supplementation**

Twice daily, the subjects received either a 250-mL protein-supplemented beverage containing 15 g protein (MPC80; milk protein concentrate), 7.1 g lactose, 0.5 g fat, and 0.4 g calcium, or a matching placebo supplement containing no protein, 7.1 g lactose, and 0.4 g calcium (FrieslandCampina Consumer Products Europe, Wageningen, the Netherlands). All beverages were vanilla flavored to mask the contents of the drinks and packages were nontransparent. The subjects consumed 1 beverage directly after breakfast and 1 beverage directly after lunch. Staff members and subjects were blinded toward treatment allocation until completion of data analysis.

**Body Composition**

Height was measured at baseline with a wall-mounted stadiometer to the nearest 0.1 cm. Body weight was measured in the fasted state to the nearest 0.1 kg with a calibrated digital scale (ED-6-T; Berkel, Rotterdam, The Netherlands). In the fasted state, lean body mass, fat mass, and bone mineral density were measured by DXA (Lunar Prodigy Advance; GE Health Care, Madison, WI).

**Maximum Strength and Physical Performance**

Maximum strength was assessed by 1-RM strength tests on leg-press and leg-extension machines (Technogym, Rotterdam, the Netherlands). During a first familiarization session, the proper lifting technique was practiced, after which maximum strength was estimated. In a second session, 1-RM strength was determined.\textsuperscript{31} Handgrip strength was measured using a hydraulic hand dynamometer (Jamar, Jackson, MI). Three consecutive measures of handgrip strength (kg) at both hands were recorded to the nearest 0.5 kg with subjects sitting in an upward position and the arm in a 90-degree angle. Physical performance was assessed by the SPPB, which consists of 3 components: balance, gait speed, and chair rise ability.\textsuperscript{31} Scores of 1 to 4 were based on categories of performance in the balance tests, on the time necessary to complete the walk, and on the time needed to perform the chair-rise test. A summary performance score of 0 to 12 was calculated by summing the scores of the tests.

**Blood Sampling**

Following an overnight fast, blood samples were collected in EDTA-containing and serum tubes. EDTA-containing tubes were centrifuged at 1000g at 4°C for 10 minutes and serum tubes were centrifuged 90 minutes after the blood collection at 1000g at 20°C for 15 minutes. Aliquots of plasma and serum were frozen in liquid nitrogen and stored at −80°C. Plasma glucose concentrations were measured with a COBAS FARA analyzer (Uni Kit III; Roche, Basel, Switzerland). Plasma insulin concentrations were measured by radioimmunoassay (Insulin RIA Kit; LINCO Research Inc, St Charles, MO). Serum creatinine concentrations were measured by using Roche Modular System P (Roche Diagnostics GmbH, Mannheim, Germany).

**Dietary Intake**

The subjects recorded their food intake for 3 days. The days of recording were randomly assigned so that all days of the week, including weekend days, were equally represented. Trained dieticians gave oral and written instructions about recording type of foods and estimating portion sizes in household measures. During a second visit, dieticians checked the food records for completeness, obtained additional information about unclear items or amounts, and used examples of household measures to improve the estimation of...
portion sizes. Dietary intake data were coded (type of food, time of intake, and amount) and energy and macronutrient intakes were calculated using a food calculation system (BAS nutrition software 2004, Arnhem, The Netherlands) in which the Dutch food composition database 2006 was included.

Health Status

Overall health status of the subjects was assessed using the 12-Item Short Form Health Survey (SF-12). The SF-12 generates a physical composite score (PCS12) and mental composite score (MCS12). Higher physical and mental composite scores indicate better health.32

Blood Pressure

After 10 minutes of supine rest, 4 blood pressure measurements with 2-minute intervals were performed in the morning following an overnight fast, using a validated automatic blood pressure device (Omron HEM-907, Lake Forest, IL). The first measurement was discarded and the subsequent 3 measurements were averaged.

Cognitive Function

The Mini-Mental State Examination (MMSE) was used to assess cognitive function.33 The score ranges from 0 to 30. A higher score represents better cognitive function.

Statistical Analysis

Sample size was calculated based on an expected difference in lean body mass of 1.1 kg between groups.34 With an SD of 1.4 kg, a minimum of 24 subjects per treatment group would be required to detect a difference (power = 80%, α = 0.05). With an expected dropout rate of 25%,35,36 a sample size of 30 subjects per treatment group was considered adequate. Data analysis was performed by the intention-to-treat principle and according to a predefined data analysis plan. Means for baseline and follow-up data were expressed with SD, SEM, or 95% confidence intervals (95% CI). Baseline characteristics were compared between treatment groups using an independent Student t test. Differences between treatments over time were analyzed using mixed linear models with Toeplitz covariance structure. Time, treatment, and their interaction were defined as fixed factors and subject was defined as a random factor. All statistical analyses were performed using SPSS Statistics v19 (SPSS Inc, Chicago, IL). An α-level of 0.05 was used to determine statistical significance.

Results

Between December 2009 and October 2010, 686 subjects were invited to participate in the study, 233 subjects were screened, and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Baseline Characteristics by Treatment Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Placebo (n = 31)</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>79 (6)</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>21 (68)</td>
</tr>
<tr>
<td>Weight, mean (SD), kg</td>
<td>77.4 (13.2)</td>
</tr>
<tr>
<td>Height, mean (SD), m</td>
<td>1.66 (0.08)</td>
</tr>
<tr>
<td>BMI, mean (SD), kg/m²</td>
<td>28.2 (4.6)</td>
</tr>
<tr>
<td>MMSE, mean (SD), points</td>
<td>28.1 (1.8)</td>
</tr>
<tr>
<td>PCS12, mean (SD), points</td>
<td>42.8 (9.8)</td>
</tr>
<tr>
<td>MCS12, mean (SD), points</td>
<td>56.6 (8.2)</td>
</tr>
<tr>
<td>Glucose, mean (SD), mmol/L</td>
<td>5.2 (0.5)</td>
</tr>
<tr>
<td>Insulin, mean (SD), µIU/L</td>
<td>18.1 (6.7)</td>
</tr>
<tr>
<td>eGFR, mean (SD), ml/min/1.73 m²</td>
<td>79.3 (19.9)</td>
</tr>
<tr>
<td>Systolic BP, mean (SD), mmHg</td>
<td>143 (20)</td>
</tr>
<tr>
<td>Diastolic BP, mean (SD), mmHg</td>
<td>73 (10)</td>
</tr>
</tbody>
</table>

BMI, body mass index; BP, blood pressure; eGFR, estimated Glomerular Filtration Rate; MCS12, mental component score Short Form 12; MMSE, Mini Mental State Examination; PCS12, physical component score Short Form 12.
62 subjects were included in the study. In total, 11 subjects withdrew from the study: 5 from the protein and 6 from the placebo group. Ten subjects gave various non-study-related medical complications as reasons for their withdrawal and 1 subject gave heavy burden of the study as reason for withdrawal. For the intention-to-treat analyses, 4 dropouts were willing to have final assessments (Figure 1). The average adherence to the treatment, based on ticked calendars and nonconsumed returned beverages, was ≥98% and did not differ between groups (P > .05). Baseline characteristics are presented in Table 1 and showed no baseline differences between groups (P > .05).

Body Composition

Lean body mass increased from 47.2 (95% CI, 43.5–50.9) to 48.5 kg (95% CI, 44.8–52.1) in the protein group, and did not change in the placebo group (from 45.7 kg, 95% CI, 42.1–49.2 to 45.4 kg, 95% CI, 41.8–48.9) following 24 weeks of intervention (Figure 2: P value for treatment × time interaction = .006) The most apparent increase in lean mass in the protein group was in the extremities. Appendicular lean mass increased from 20.1 (95% CI, 18.3–21.8) to 21.0 kg (95% CI, 19.2–22.7) in the protein group only (Table 2: P value for treatment × time interaction <.001). Fat mass increased from 27.8 (95% CI, 23.8–31.4) to 28.5 kg (95% CI, 24.7–32.3) in the protein group and did not increase in the placebo group (from 28.4 kg, 95% CI, 24.8–32.1 to 27.9 kg, 95% CI, 24.2–31.6; P value for treatment × time interaction <.001) (Figure 2).

Strength and Physical Performance

Strength and physical performance data are presented in Table 3. Leg-press and leg-extension strength improved over time in both the protein and placebo groups (P < .001) with no significant treatment × time interaction effect. In accordance, physical performance (SPPB) improved significantly from 8.0 (95% CI, 7.2–8.9) to 9.5 points (95% CI, 8.6–10.3) in the protein group and from 7.9 (95% CI, 7.0–8.8) to 9.2 points (95% CI, 8.3–10.1) in the placebo group with no treatment × time interaction (P > .05).

Blood Measurements and Renal Function

Baseline plasma glucose and insulin concentrations are presented in Table 1. Glucose and insulin concentrations did not change over time in either group (data not shown). The estimated glomerular filtration rates (eGFR) did not differ between groups at baseline (Table 1) and did not significantly change from 80.6 (95% CI, 75.6–85.6) to 81.6 mL/min/1.73 m² (95% CI, 76.5–86.7) in the protein group with no significant treatment × time interaction effect (P > .05).

Dietary Intake

Dietary intake data are presented in Table 4. Baseline habitual protein intake was 1.0 (95% CI, 0.9–1.1) g/kg-body weight/d and did not change over time in either group (P > .05). When including the dietary protein supplements (ie, 30 g/d), daily protein intake increased from 1.0 (95% CI, 0.9–1.1) to 1.3 (95% CI, 1.1–1.5) g/kg-body weight/d in the protein group. Fat and carbohydrate intake did not differ between groups and remained similar over time. Habitual energy intake did not change significantly over time in either group (P > .05).

Health Status, Blood Pressure, and Cognitive Function

Health status (SF-12 scores), blood pressure, and cognitive function (MMSE) parameters did not differ between groups at baseline (Table 1) and did not change over time in either group (data not shown).

Discussion

The present study showed that 24 weeks of resistance-type exercise training improved muscle strength and functional performance in frail elderly men and women. However, dietary protein supplementation was shown to be required during resistance-type exercise training to allow an increase in skeletal muscle mass in this frail elderly population.

A large number of potential participants were recruited and screened to allow inclusion of an adequate sample of frail elderly subjects (Figure 1). The latter resulted in the selection of 62 elderly subjects who met the defined frailty criteria. These criteria have

<table>
<thead>
<tr>
<th>Variable</th>
<th>Placebo 0 wk</th>
<th>Placebo 12 wk</th>
<th>Placebo 24 wk</th>
<th>Protein 0 wk</th>
<th>Protein 12 wk</th>
<th>Protein 24 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight, kg, mean (95% CI)</td>
<td>77.4 (72.2–82.7)</td>
<td>77.7 (72.4–82.9)</td>
<td>76.9 (71.6–82.2)</td>
<td>79.5 (74.2–84.8)</td>
<td>80.3 (75.1–85.6)</td>
<td>81.3 (76.0–86.6)</td>
</tr>
<tr>
<td>Lean mass, kg, mean (95% CI)</td>
<td>45.7 (42.1–49.2)</td>
<td>45.6 (42.1–49.2)</td>
<td>45.4 (41.8–48.9)</td>
<td>47.2 (43.5–50.9)</td>
<td>48.4 (44.7–52.1)</td>
<td>48.5 (44.8–52.1)</td>
</tr>
<tr>
<td>Appendicular lean mass, kg, mean (95% CI)</td>
<td>19.3 (17.6–20.9)</td>
<td>19.3 (19.7–21.0)</td>
<td>19.1 (17.5–20.8)</td>
<td>20.1 (18.3–21.8)</td>
<td>20.4 (18.6–22.1)</td>
<td>21.0 (19.2–22.7)</td>
</tr>
<tr>
<td>Fat mass, kg, mean (95% CI)</td>
<td>28.4 (24.8–32.1)</td>
<td>28.5 (24.8–32.1)</td>
<td>27.9 (24.2–31.6)</td>
<td>27.8 (24.0–31.6)</td>
<td>27.6 (23.8–31.4)</td>
<td>28.5 (24.7–32.3)</td>
</tr>
<tr>
<td>Bone mineral content, kg, mean (95% CI)</td>
<td>2.5 (2.3–2.7)</td>
<td>2.5 (2.3–2.8)</td>
<td>2.5 (2.3–2.8)</td>
<td>2.5 (2.3–2.7)</td>
<td>2.5 (2.2–2.7)</td>
<td>2.5 (2.3–2.7)</td>
</tr>
</tbody>
</table>

CI, confidence interval.

Intention-to-treat data were analyzed using a mixed linear model (*n = 62; 'n = 56).
been reported to be highly predictive for falls, hospitalization, disability, and mortality.27 Confirming their frailty, the selected subjects showed a low baseline physical performance,28 and poor leg29 and handgrip strength29 (Table 3).

Resistance-type exercise training has been established as an effective interventional strategy to counteract the age-related loss of muscle strength and performance in healthy and frail elderly people.20,23–26 In agreement, we observed a substantial 43% ± 4% and 37% ± 3% increases in leg strength and 1.3 ± 0.3 and 1.5 ± 0.3 point improvements in physical performance (SPPB) in the placebo and protein supplemented group, respectively (Table 3). The improvements in physical performance were mainly attributed to a decline in the time required to rise from a chair following 24 weeks of training. These findings are consistent with previous results from shorter exercise training interventions among various elderly populations24,26 and translate to a reduced risk for disability,28 institutionalization,31 and mortality.31 The subjects attended 83% ± 2% of the scheduled training sessions and performed on average 65% ± 1% of their 1-RM in 4 sets on the leg-press and leg-extension machines. The excellent adherence confirms the feasibility of such an intense, supervised resistance-type exercise training program for the frail elders. Government and health care workers should be encouraged to facilitate the implementation of resistance-type exercise training in such frail elderly population.

We provided a dietary protein supplement immediately after breakfast and lunch with the intention to further augment the skeletal muscle adaptive response to resistance-type exercise training. By supplementing 15 g protein twice daily, protein intake increased to more than 25 g with each main meal in the protein-supplemented group.40 In the placebo group, the subjects continued to ingest relatively small amounts of dietary protein at breakfast (13 g) and lunch (20 g) during the entire intervention period (Table 4). It has been reported that these relatively small amounts of protein are insufficient to allow a proper increase in postprandial muscle protein synthesis rates in elderly subjects,41 thereby compromising muscle mass maintenance. We hypothesized that increasing dietary protein intake at breakfast and lunch would stimulate muscle protein synthesis42 and augment net muscle protein accretion during 24 weeks of resistance-type exercise training. Confirming our hypothesis, we observed a significant

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Placebo 0 wk</th>
<th>Placebo 12 wk</th>
<th>Placebo 24 wk</th>
<th>Protein 0 wk</th>
<th>Protein 12 wk</th>
<th>Protein 24 wk</th>
<th>Treatment × Time Interaction</th>
<th>Treatment Effect</th>
<th>Time Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg press strength, kg, mean (95% CI)*</td>
<td>116 (101–130)</td>
<td>148 (132–162)</td>
<td>162 (147–178)</td>
<td>124 (109–139)</td>
<td>156 (141–171)</td>
<td>169 (154–184)</td>
<td>0.96</td>
<td>0.41</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Leg extension strength, kg, mean (95% CI)*</td>
<td>58.3 (51.7–64.9)</td>
<td>74.1 (66.8–81.4)</td>
<td>79.3 (72.2–86.4)</td>
<td>56 (49.5–62.7)</td>
<td>70.0 (62.7–77.3)</td>
<td>76.8 (69.8–83.9)</td>
<td>0.83</td>
<td>0.53</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Handgrip strength, kg, mean (95% CI)*</td>
<td>26.7 (23.1–30.3)</td>
<td>26.7 (23.1–30.3)</td>
<td>27.1 (23.5–30.8)</td>
<td>25.9 (22.3–29.5)</td>
<td>27.2 (23.6–30.9)</td>
<td>28.1 (24.5–31.7)</td>
<td>0.35</td>
<td>0.92</td>
<td>0.12</td>
</tr>
<tr>
<td>SPPB, points, mean (95% CI)*</td>
<td>7.9 (7.0–8.8)</td>
<td>8.3 (7.3–9.1)</td>
<td>9.2 (8.3–10.1)</td>
<td>8.0 (7.2–8.9)</td>
<td>9.2 (8.3–10.1)</td>
<td>9.5 (8.6–10.3)</td>
<td>0.23</td>
<td>0.46</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Gait speed, s, mean (95% CI)*</td>
<td>5.4 (4.8–6.1)</td>
<td>5.6 (5.0–6.3)</td>
<td>5.3 (4.6–5.9)</td>
<td>5.3 (4.6–6.0)</td>
<td>5.3 (4.6–6.0)</td>
<td>5.2 (4.5–5.9)</td>
<td>0.41</td>
<td>0.72</td>
<td>0.18</td>
</tr>
<tr>
<td>Chair rise, s, mean (95% CI)*</td>
<td>17.3 (14.8–19.9)</td>
<td>16.4 (13.9–19.0)</td>
<td>13.2 (10.5–15.9)</td>
<td>15.6 (13.0–18.1)</td>
<td>13.6 (10.9–16.3)</td>
<td>13.5 (10.7–16.2)</td>
<td>0.30</td>
<td>0.34</td>
<td>0.01</td>
</tr>
</tbody>
</table>

CI, confidence interval; SPPB, Short Physical Performance Battery.

Intention-to-treat data were analyzed using a mixed linear model (*n = 62; ′n = 57).

### Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Placebo 0 wk</th>
<th>Placebo 12 wk</th>
<th>Placebo 24 wk</th>
<th>Protein 0 wk</th>
<th>Protein 12 wk</th>
<th>Protein 24 wk</th>
<th>Treatment × Time Interaction</th>
<th>Treatment Effect</th>
<th>Time Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake, MJ, mean (95% CI)*</td>
<td>7.8 (7.0–8.6)</td>
<td>7.5 (6.7–8.4)</td>
<td>7.8 (7.0–8.7)</td>
<td>8.6 (7.8–9.4)</td>
<td>8.0 (7.2–8.8)</td>
<td>8.2 (7.4–9.1)</td>
<td>0.70</td>
<td>0.29</td>
<td>0.21</td>
</tr>
<tr>
<td>Protein intake, g, mean (95% CI)*</td>
<td>76.4 (68.3–84.5)</td>
<td>70.0 (61.8–78.3)</td>
<td>77.7 (69.2–86.2)</td>
<td>77.7 (69.5–85.9)</td>
<td>74.2 (65.9–82.5)</td>
<td>83.5 (75.2–91.9)</td>
<td>0.61</td>
<td>0.47</td>
<td>0.004</td>
</tr>
<tr>
<td>Protein intake, g/kg-bw/d, mean (95% CI)*</td>
<td>1.0 (0.9–1.1)</td>
<td>0.9 (0.8–1.0)</td>
<td>0.9 (0.8–1.1)</td>
<td>1.0 (0.9–1.1)</td>
<td>1.0 (0.9–1.1)</td>
<td>1.0 (0.9–1.1)</td>
<td>0.79</td>
<td>0.96</td>
<td>0.64</td>
</tr>
<tr>
<td>Protein intake including supplement, g/kg-bw/d, mean (95% CI)*</td>
<td>1.0 (0.9–1.1)</td>
<td>0.9 (0.8–1.0)</td>
<td>0.9 (0.8–1.1)</td>
<td>1.0 (0.9–1.1)</td>
<td>1.3 (1.2–1.5)</td>
<td>1.3 (1.1–1.5)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Protein at breakfast, g, mean (95% CI)*</td>
<td>13.2 (10.8–15.6)</td>
<td>11.9 (9.4–14.3)</td>
<td>11.9 (9.4–14.5)</td>
<td>11.8 (9.3–14.2)</td>
<td>13.0 (10.5–15.5)</td>
<td>12.8 (10.3–15.3)</td>
<td>0.08</td>
<td>0.92</td>
<td>0.99</td>
</tr>
<tr>
<td>Protein at lunch, g, mean (95% CI)*</td>
<td>17.7 (14.9–20.4)</td>
<td>20.3 (17.7–23.0)</td>
<td>16.2 (13.3–19.0)</td>
<td>18.9 (16.2–21.6)</td>
<td>22.1 (19.4–24.8)</td>
<td>20.9 (18.2–23.6)</td>
<td>0.10</td>
<td>0.12</td>
<td>0.003</td>
</tr>
<tr>
<td>Protein at dinner, g, mean (95% CI)*</td>
<td>33.5 (28.0–39.0)</td>
<td>32.5 (26.9–38.0)</td>
<td>36.6 (30.8–42.4)</td>
<td>34.8 (29.2–40.3)</td>
<td>35.4 (29.8–41.0)</td>
<td>40.0 (34.4–45.7)</td>
<td>0.82</td>
<td>0.46</td>
<td>0.04</td>
</tr>
<tr>
<td>Protein intake, en%, mean (95% CI)*</td>
<td>170.1 (159–181)</td>
<td>160.1 (148–171)</td>
<td>169.1 (157–181)</td>
<td>157.1 (146–169)</td>
<td>163.1 (152–175)</td>
<td>175.1 (163–187)</td>
<td>0.07</td>
<td>0.89</td>
<td>0.04</td>
</tr>
<tr>
<td>Fat intake, en%, mean (95% CI)*</td>
<td>35.0 (32.8–37.2)</td>
<td>35.3 (33.0–37.5)</td>
<td>34.1 (31.8–36.5)</td>
<td>32.7 (30.5–35.0)</td>
<td>31.9 (29.6–34.1)</td>
<td>33.1 (30.8–35.3)</td>
<td>0.38</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Carbohydrate intake, en%, mean (95% CI)*</td>
<td>44.6 (41.8–47.4)</td>
<td>45.6 (42.8–48.4)</td>
<td>44.5 (41.6–47.4)</td>
<td>47.5 (44.6–50.3)</td>
<td>48.0 (45.2–50.9)</td>
<td>46.2 (43.3–49.0)</td>
<td>0.74</td>
<td>0.21</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Bw, body weight; CI, confidence interval; en%, energy percentage.

Intention-to-treat data were analyzed using a mixed linear model (*n = 61; ′n = 60).
1.3 ± 0.4 kg increase in lean body mass in the protein-supplemented group. In contrast, no net increase in lean body mass was observed in the placebo group.

The muscle mass gain observed in the protein-supplemented group entirely offset the decline in muscle mass that is generally reported in elderly people. Instead of the annual loss of 0.5 to 1.0 kg muscle tissue, we observed a net 1.3 kg increase in lean mass in the protein-supplemented group. In the placebo group, the exercise intervention prevented a measurable decline in lean muscle mass, but in contrast to the protein group, no net gain in lean mass was observed. Nonetheless, the preservation of muscle tissue will reduce the risk of developing chronic metabolic diseases, such as obesity and type 2 diabetes.

Despite a greater increase in muscle mass, protein supplementation did not further augment the increase in muscle strength and physical performance following 24 weeks of resistance-type exercise training. The latter is not surprising, as a disproportionate increase in muscle strength generally occurs during the first few months of resistance-type exercise training. This increase in muscle strength was primarily attributed to changes in neuromuscular activation (i.e., motor unit recruitment) and/or increases in muscle quality. The increase in skeletal muscle mass in the protein- as opposed to the placebo-supplemented group, will likely allow a further increase in muscle strength and performance as time progresses. This would translate into a greater training efficiency over a more prolonged training duration.

In the present study, we showed that dietary protein supplementation was required to gain muscle mass during prolonged exercise intervention in a frail elderly population. This protein supplementation (30 g/d) increased the habitual protein intake from 1.0 to 1.4 kg/kg/d and did not result in a reduction in habitual energy intake (Table 4). Furthermore, the greater protein intake was not accompanied by any health complaints and also did not seem to affect renal function throughout the intervention period. Our present findings strongly advocate the ingestion of more protein during resistance-type exercise training in frail elderly people as a means to attenuate or even reverse the loss of muscle mass with aging and, as such, prevent the progression of frailty and functional decline.

Conclusion

We conclude that resistance-type exercise training represents an effective and feasible strategy to improve strength and physical performance in frail elderly people. Daily dietary protein supplementation (15 g protein, twice daily) is required to allow muscle mass gain during prolonged resistance-type exercise training in frail elderly men and women.

Acknowledgments

We gratefully acknowledge the expert assistance of Antoine Zorenc, Lex Verdijk, Thomas Cammellbeek, Lucy Okma, Jantien Takens, Fenglian Hu, Liencke Homans, and all volunteers and students who participated in this study. Furthermore, we greatly acknowledge all the elderly subjects who volunteered to participate in this study.

References


