

Efficacy of Whey Protein Supplementation on Resistance Exercise–Induced Changes in Lean Mass, Muscle Strength, and Physical Function in Mobility-Limited Older Adults

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Background. Whey protein supplementation may augment resistance exercise-induced increases in muscle strength and mass. Further studies are required to determine whether this effect extends to mobility-limited older adults. The objectives of the study were to compare the effects of whey protein concentrate (WPC) supplementation to an isocaloric control on changes in whole-body lean mass, mid-thigh muscle cross-sectional area, muscle strength, and stair-climbing performance in older mobility-limited adults in response to 6 months of resistance training (RT).

Methods. Eighty mobility-limited adults aged 70–85 years were randomized to receive WPC (40 g/day) or an isocaloric control for 6 months. All participants also completed a progressive high-intensity RT intervention. Sample sizes were calculated based on the primary outcome of change in whole-body lean mass to give 80% power for a 0.05-level, two-sided test.

Results. Lean mass increased 1.3% and 0.6% in the WPC and control groups, respectively. Muscle cross-sectional area was increased 4.6% and 2.9% in the WPC and control groups, respectively, and muscle strength increased 16%–50% in WPC and control groups. Stair-climbing performance also improved in both groups. However, there were no statistically significant differences in the change in any of these variables between groups.

Conclusions. These data suggest that WPC supplementation at this dose does not offer additional benefit to the effects of RT in mobility-limited older adults.

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THE age-related loss of muscle mass, sarcopenia, is associated with declines in strength and physical functioning; a combination that is strongly predictive of future disability (1,2). Various interventions have been examined to delay progression of muscle loss and prolong independence among community-dwelling older adults. Studies examining changes in muscle CSA have observed that although older adults are responsive to resistance training (RT) stimuli (3,4), muscle hypertrophy is attenuated with aging (5–7).

Whey protein concentrate (WPC) contains a disproportionate amount of essential amino acids, is readily available commercially, and is palatable; thus, it may represent an

ideal protein source to promote muscle anabolism in older individuals undergoing RT. Interestingly, in young healthy male adults, fat-free milk consumption has been shown to increase muscle size and muscle protein synthesis (MPS) in response to RT compared with isoenergetic soy protein (8) and casein, respectively (9). It is well recognized that leucine and the other branched chain amino acids (isoleucine and valine) are abundant in WPC and may be responsible for its enhanced ability to stimulate muscle protein anabolism, particularly in older adults (10,11).

To date, the effects of protein supplementation with RT on body composition, muscle hypertrophy, strength, and physical function in older adults have yielded mixed results

(12–19). More importantly, most studies have focused on healthy older adults with very limited data from trials on mobility-limited older adults (15), and where nutritional and not specifically protein supplementation was a focus (19). Thus, the purpose of this study was to examine the chronic effects of WPC and RT in mobility-limited older adults on changes in whole-body lean mass, mid-thigh muscle CSA, muscle strength, and physical functioning. We hypothesized that compared with an isocaloric control, a daily 40 g supplement of WPC would increase whole-body lean mass, mid-thigh muscle CSA, muscle strength, and physical functioning in older mobility-limited adults in response to 6 months of RT.

METHODS

Participants

Eighty community-dwelling older adults participated in this randomized, double-blind, controlled study (Figure 1). Eligibility criteria are described (Supplementary Table 1). All participants were required to be sedentary (no structured exercise during the previous 6 months). Participants gave informed consent. Tufts University Health Sciences Campus Institutional Review Board approved this study. Allocation to the WPC ($n = 42$) or control ($n = 38$) group was conducted by a research assistant unaffiliated with this study who maintained the randomization schedule and communicated the randomization to the research dietitian. The randomization schedule was developed by the study statistician.

Baseline Screening of Physical Functioning

All participants were required to have a short physical performance battery (SPPB) score ≤ 10 . The SPPB consists of timed standing balance, gait speed, and timed chair-rise assessments (1). Performance for each of these tasks is scored between 0 and 4, with a summary score of 0–12.

RT Protocol

The RT protocol was a supervised progressive program, three times per week for 6 months, which entailed leg press, seated row, leg extension, chest press, and leg curl. Participants performed the training exercises progressing to 80% of their one repetition maximum (1-RM). The 1-RM was assessed at baseline and re-evaluated monthly. Participants initially performed 2 sets of 10 repetitions progressing to 3 sets of 12 repetitions throughout the 6-month intervention period. Each set was followed by a 1- to 2-min rest period. Resistance training was preceded by 5 min of lower extremity “warm-up” (walking or stationary cycling). All training was performed on Cybex VR2 machines (Cybex International, Medway, MA). Adherence to RT was quantified by average attendance at scheduled sessions and the average exercise intensity (% 1-RM) for the knee extension and leg press exercises achieved over the length of the trial.

Whey Protein Supplementation

Innovative Food Processors Inc. (Faribault, MN) provided the WPC and control supplements. Participants were randomized to receive either 40 g/day of WPC (one serving contains 20 g protein, 25 g maltodextrin, 1 g fat; 189 kcal [791 kJ]) or an isocaloric control (45 g maltodextrin, 1 g fat; 189 kcal [791 kJ]). A research dietitian, blinded to the randomization schedule provided by the study statistician, distributed the supplements to participants weekly in exchange for returned packages to monitor adherence. Supplements were in powder form contained in numerically coded packages. Participants consumed two servings per day, one in the morning after breakfast and one in the evening after their evening meal. On the days that participants performed RT, one serving of the supplement was consumed immediately following RT. Participants were instructed to consume their regular food intake in addition to the supplements. To provide an additional measure of adherence, WPC and control also contained 200 mg of para-aminobenzoic acid (PABA). A single random-spot urine sample was collected from each participant monthly to confirm adherence. Urinary PABA was measured by a modified colorimetric assay (20).

Determination of Dietary Intake

Participants recorded their food intake using a 3-day diet record at baseline and month 6. Dietary intake data were analyzed using Nutrition Data System for Research software version 2007 (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN). We reported dietary intake from food sources alone (excluding WPC/control supplement) and also reported dietary intake (including the WPC/control supplement as well as accounting for adherence).

Muscle Strength and Power

Leg press and knee extension strength and power were evaluated using pneumatic bilateral seated leg press and knee extension equipment (K400, Keiser Sports Health Equipment Inc., Fresno, CA). Strength defined as the 1-RM was measured for both the leg press and knee extensors, as reported previously (21).

Peak power was assessed for both knee extensors and leg press. Following a baseline 1-RM measurement, each participant performed five repetitions, as fast as possible, at 40% and 70% 1-RM. The highest power output achieved during each of these five repetitions by a participant was designated as their peak power. The test–retest reliability for this assessment in our laboratory is excellent (leg extensor: intraclass correlation [ICC] = 0.95) (22).

Body Composition

Dual energy x-ray absorptiometry.—Whole body, regional fat, and lean mass were assessed using DXA (Hologic, Discovery A v12.3, Hologic Inc., Bedford, MA) following

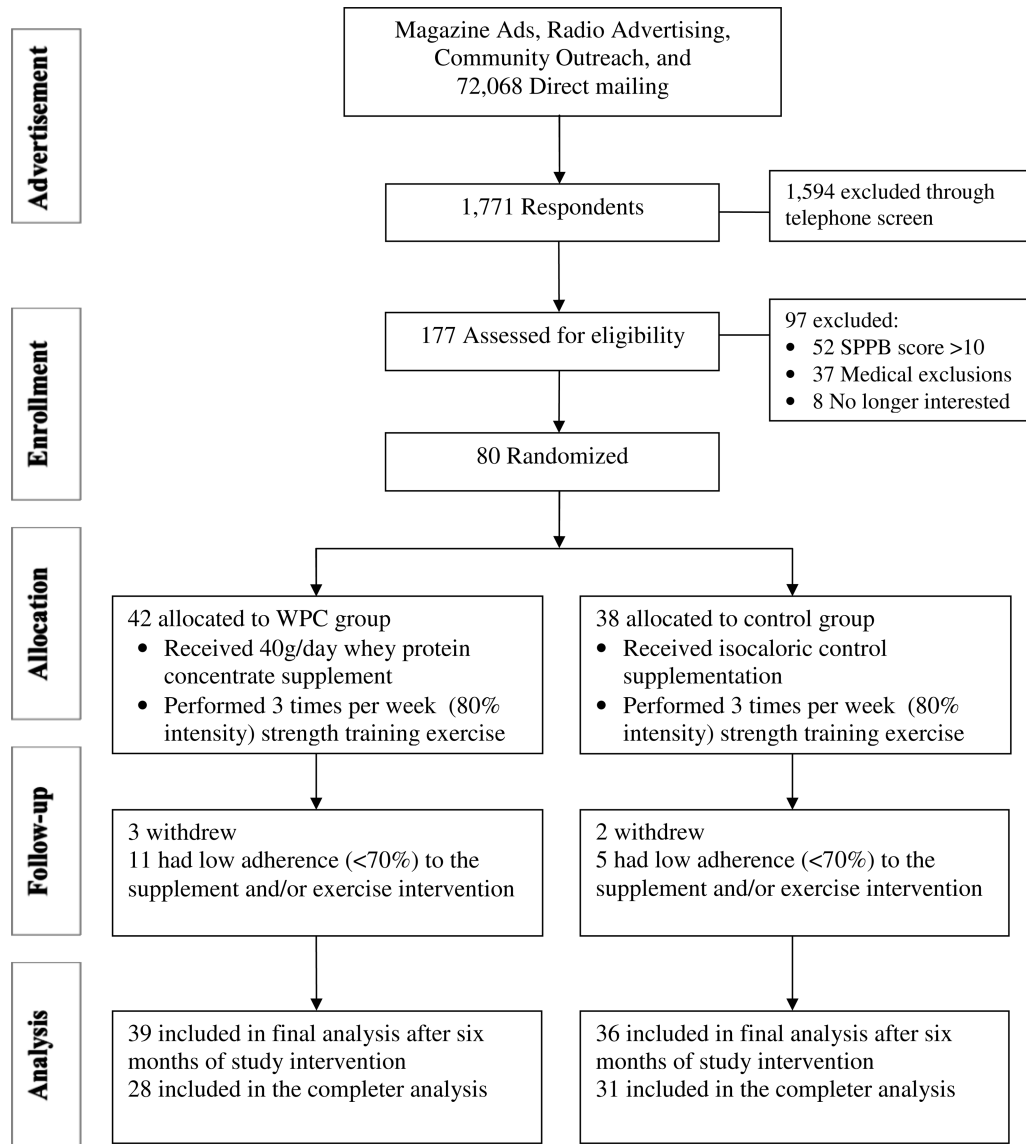


Figure 1. Consort diagram of study recruitment, enrollment, and randomization. SPPB = short physical performance battery.

an 8-hour fast. The test–retest reliability of this method of estimating total lean mass is high (C.V. < 4%) (23).

Computed tomography.—Regional changes in skeletal muscle CSA were measured by CT following an 8-hour fast. CT imaging was performed on the nondominant thigh, at the midpoint of the femur using a Siemens Somatom Scanner (Erlangen, Germany). Scans were analyzed for normal-density muscle (35–100 Hounsfield units [HU]), low-density muscle (0–34 HU), total muscle (normal-density muscle plus low-density muscle), subcutaneous, and intermuscular fat CSA by a technician in a blinded manner using SliceOmatic v4.2 software (Montreal, Canada), as described previously (24). Total muscle CSA was measured in the range of 0–100 HU and calculated as the sum of low-density muscle and normal-density muscle CSA.

Physical Function

Stair-climb and chair-rise performance.—In addition to the SPPB, separate assessments of stair-climb and chair-rise times were performed. For the stair-climb assessment, participants ascended a 10-rise set of stairs as fast as possible. Participants were not permitted to hold on to the railing or use assistive devices. The average of two attempts was recorded. Repeated chair-rise time (10×) was determined on a standard chair with the participant holding their arms across the chest. The average of two attempts was recorded. The repeated chair-rise time has excellent reliability (ICC = .933 vs ICC = .124, respectively) (25).

Four-hundred-meter walk time.—Participants were asked to walk 10 laps of a 20-m course at their usual pace. Rest intervals were permitted, while standing, for up to 60

seconds. Gait speed was calculated from the time and distance completed for each participant.

STATISTICS

The primary outcome for this study was the change in lean mass measured by DXA between WPC and control groups. Secondary outcomes included mid-thigh muscle CSA, muscle strength, stair-climb performance, and other measures of physical functioning. Sample sizes were calculated to give 80% power for a 0.05-level, two-sided test, using the above outcomes. All statistical analyses were performed at the two-tailed, .05 level of significance using version 11 of SYSTAT (Systat Software, Inc., San Jose, CA) and version 9.2 of SAS for Windows (SAS Institute, Cary, NC).

Continuous baseline characteristics (eg, age, BMI, and baseline strength) were compared across treatments using a two-sample *t* test. All outcomes were analyzed using analysis of covariance (ANCOVA) models in which the change from baseline was the response, use of WPC was the study factor, and the baseline value was the covariate. We also looked for sex differences and whether sex modified any effect of WPC by including a sex-by-whey interaction in the models. All data are reported as mean ± standard deviation. For all outcome variables, point estimates for the difference in mean change between WPC and control were calculated along with 95% confidence intervals.

The above-mentioned treatment group comparisons were carried out in the spirit of “Intent-to-Treat.” A secondary analysis was performed on those participants adherent with both the resistance exercise and nutritional intervention. Adherence was defined as participants that attended 70% of the scheduled resistance exercise sessions and did not have two consecutive negative PABA spot urine analyses during the trial. With the exception of normal-density muscle CSA and 400 m gait speed, the results did not differ for the subsequent “completers” analyses. Therefore, all data presented are based on the “Intent-to-Treat” analyses.

RESULTS

Baseline Characteristics of Participants

Baseline characteristics of participants are displayed in Table 1. There were no differences between the groups for any of the baseline characteristics.

Adverse Events and Intervention Adherence

The groups did not differ with respect to serious or non-serious adverse events (Supplementary Table 2). A total of five participants withdrew from the trial (three in WPC and two in control). The adherence to the supplement consumption based on the percentage of participants who did not have two consecutive negative PABA urine analyses was

Table 1. Baseline Participant Characteristics

Characteristics	Whey (n = 42)	Control (n = 38)	p
	N (%) or Mean ± SD	N (%) or Mean ± SD	
Age	78.0±4.0	77.3±3.9	0.43
Height (cm)	164.2±7.7	165.1±9.6	0.64
Body mass (kg)	73.0±10.8	73.8±11.2	0.75
BMI (body mass/height ²)	27.0±3.2	26.9±3.1	0.93
SPPB	8.5±1.2	8.5±1.7	0.87
Medical diagnoses*	3 (0–6)	3 (0–6)	0.95
Number of medications*	4 (0–8)	3 (0–10)	0.46
Gender, female	25 (60%)	22 (58%)	1.00
Ethnicity			0.53
Asian or Pacific Islander	2 (5%)	1(2%)	
Black, not of Hispanic origin	6 (14%)	7 (18%)	
White, not of Hispanic origin	28 (67%)	28 (74%)	
Other or unknown	6 (14%)	2 (5%)	

*Median (range).

67% and 84% in WPC and control, respectively. Adherence to the supplement consumption (measured by return of empty supplement packets) was similar between groups and averaged 72.1% ± 29.3% and 82.3% ± 21.9% in WPC and control, respectively. Adherence to the exercise sessions was 79.9% ± 20.8% and 80.2% ± 21.7% in WPC and control, respectively. The average exercise intensity achieved during training sessions for the knee extensors and leg press combined was 76% ± 17.4% and 80% ± 2.8% (% 1-RM) in WPC and control, respectively, and was not different between groups.

Dietary Intake

Three-day diet records (excluding supplement intake) revealed a significant decrease in total energy intake with no significant differences between groups (Table 2). The observed reductions in total energy intake appeared to be driven by small but significant decreases in total carbohydrate, protein, and total fat intake (Table 2). When dietary intake from food was combined with WPC/control supplement intake (adjusted for adherence), total energy intake was increased at 6 months in both groups (*p* < .001) and was not different between groups (*p* < .09). Total carbohydrate intake in control was 50 g/day different than WPC at 6 months. Total protein was greater in WPC compared with control by 18 g/day at 6 months (*p* < .001).

Body Composition (DXA and CT)

Total body lean mass increased 1.3% and 0.6% in the WPC and control groups, respectively, but was not significantly different between groups (*p* = .46). Total body mass (scale weight) increased in both groups over time with no significant difference between groups. Total body fat mass was also not affected over time in either group (Table 3).

Analysis of the mid-thigh composition by CT scan revealed a statistically significant increase in total muscle

Table 2. Three-Day Mean Dietary Intake* of Selected Nutrients in Total Sample

Nutrient	Whey	Control	Point Estimates	P Value
	(N = 30)	(N = 29)	(95% CI) [†]	Time
<i>Intake excluding whey/control</i>				
Energy (total kcal/d)				.0159
Baseline	1639 ± 376	1756 ± 540	-59 (-201,83)	
Six months	1464 ± 309	1580 ± 488		
Carbohydrate (total g/d)				<.0001
Baseline	200 ± 62	220 ± 77	-9 (-30,12)	
Six months	176 ± 45	193 ± 63		
Protein (total g/d)				<.0001
Baseline	71 ± 17	72 ± 19	-6 (-14,1)	
Six months	64 ± 15	68 ± 18		
Fat (total g/d)				.0258
Baseline	64 ± 27	64 ± 27	-3 (-12,5)	
Six months	58 ± 25	56 ± 25		
<i>Intake including whey/control</i>				
Energy (total kcal/d)				<.0001
Baseline	1639 ± 176	1756 ± 540	-128 (-276,20)	
Six months	1702 ± 324	1875 ± 476		
Carbohydrate (total g/d)				<.0001
Baseline	200 ± 62	220 ± 77	-50 (-73,-27)	
Six months	208 ± 47	262 ± 63		
Protein (total g/d)				<.0001
Baseline	71 ± 17	72 ± 19	18 (8,29)	
Six months	89 ± 22	69 ± 19		
Fat (total g/d)				.0153
Baseline	64 ± 23	64 ± 27	-4 (-12,5)	
Six months	58 ± 22	60 ± 25		

*The average daily dietary intake was obtained from self-reported 3-d food logs.

[†]Mean change whey (6 month less baseline) minus change in control, and the corresponding 95% CI.

Table 3. Body Composition Analysis Using Dual X-Ray Absorptiometry and Mid-Thigh Muscle Cross-Sectional Area Using Computed Tomography

Body Composition	Whey	Control	Point Estimates	P Value
	(N = 42)	(N = 38)	(95% CI)*	Time
Total body mass [†] (kg)				<.001
Baseline	73.5 ± 10.8	73.7 ± 11.4	0.05 (-1.24,1.33)	
Six months	75.5 ± 11.5	75.7 ± 11.6		
Total lean mass (kg)				.01
Baseline	46.7 ± 8.6	46.4 ± 8.4	0.26 (-0.43,0.95)	
Six months	47.3 ± 8.6	46.7 ± 8.4		
Total fat mass (kg)				.41
Baseline	25.9 ± 6.9	25.6 ± 7.2	-0.12 (-0.87,0.64)	
Six months	25.6 ± 6.9	25.5 ± 6.9		
Total mid-thigh CSA (cm ²)				.138
Baseline	192.4 ± 35.2	191.3 ± 41.1	2 (-5,9)	
Six months	196.4 ± 39.4	192.0 ± 36.3		
Total muscle CSA (cm ²)				<.001
Baseline	96.3 ± 21.8	97.3 ± 25.0	1 (-1,4)	
Six months	100.7 ± 21.7	100.1 ± 26.0		
Total normal-density muscle CSA (cm ²)				.011
Baseline	70.3 ± 19.7	72.0 ± 26.8	3 (-2,8)	
Six months	75.5 ± 20.4	73.7 ± 24.8		
Total low-density muscle CSA (cm ²)				.75
Baseline	26.0 ± 7.6	25.3 ± 9.6	-1 (-5,2)	
Six months	25.2 ± 8.6	26.4 ± 9.7		
Total subcutaneous adipose tissue CSA (cm ²)				.69
Baseline	83.6 ± 41.9	82.8 ± 42.6	3 (-2,7)	
Six months	85.4 ± 45.3	81.4 ± 37.7		
Total intermuscular adipose tissue CSA (cm ²)				.42
Baseline	4.8 ± 2.8	4.7 ± 2.5	-0.2 (-0.7,0.2)	
Six months	4.5 ± 2.6	4.7 ± 2.5		

*Mean change whey (6 month less baseline) minus change in control, and the corresponding 95% CI.

[†]The total body mass was obtained from a portable digital scale.

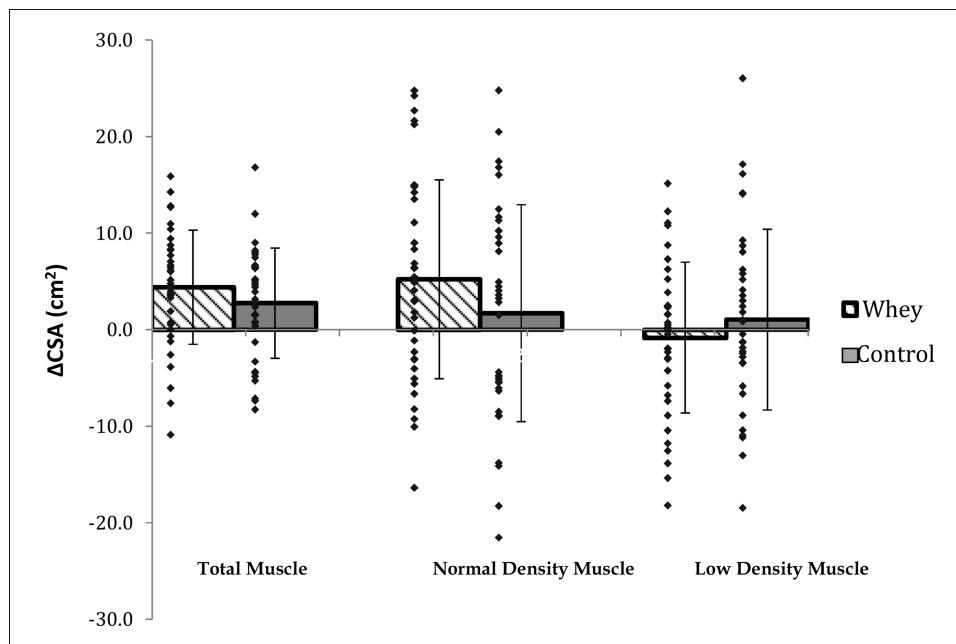


Figure 2. Plot of change in total, normal-density, and low-density muscle cross-sectional area (CSA, cm²) in whey and control.

CSA with no significant difference in change between groups (Table 3 and Figure 2). In both groups, normal- and low-density muscle CSA and intermuscular and subcutaneous fat were unchanged over time. Similar results were observed for the “completers” analysis with the exception of statistically significant increase over time in both groups for normal-density muscle CSA (8.0% and 4.3% in WPC and control, respectively; $p = 0.005$; data not shown).

Muscle Performance (1-RM Strength and Power)

Muscle strength as measured by the 1-RM increased significantly over time for all muscle groups (Table 4). However, there was no significant difference between the groups. Strength increases over time ranged from 16% to 50%.

Peak power measures increased over time for the double leg press at both 40% and 70% of the 1-RM with no difference in the change between groups (Table 4). The change in peak power at both 40% and 70% of 1-RM for the knee extensors increased significantly more in the WPC compared with control. The increases ranged from 28% to 38% in the WPC group and 8% to 21% in control.

Physical Performance Measures

With the exception of the 400-m walk, all measures of physical functioning improved significantly in both groups over time with no difference between groups (Table 5). Further examination of data from the “completers” analysis resulted in improvements in all measures of physical functioning in both groups over time but including 400-m walk time ($p = .01$; data not shown).

DISCUSSION

The main finding from this study was that total body lean mass increased in response to 6 months of progressive RT. Although the increase in lean mass in the WPC group was greater than control (1.3% vs 0.6%), these differences were not statistically significant. The analysis of changes in muscle strength, peak power, mid-thigh muscle CSA, stair-climb and chair-rise times, and SPPB score all revealed similar responses with WPC showing greater changes. However, with the exception of knee extensor power, there were no statistically significant differences in the change in measured variables between the groups. Additionally, with the exception of normal-density muscle CSA and 400 m gait speed, the results were similar when examining the “completers” analysis.

The increases in muscle strength and power, and physical functioning in response to RT were comparable to previous reports in this population (19,21,26). In addition, total muscle CSA and lean mass increased significantly in both groups. We also observed significant increases in normal-density muscle CSA over time in the “completers” analysis. Although there were no statistically significant differences between WPC and control, the reported changes all tended to favor WPC. The differences in change in muscle size could lead to important functional benefits over a longer time period.

Current data on the effects of protein supplementation with RT on body composition, muscle hypertrophy, strength, and physical function, from prior studies ranging in duration from 10 weeks to 18 months, have yielded mixed results (12–19). Furthermore, the protein dose delivered has varied between 7.4 and 15 g per serving. These differences

Table 4. Lower Extremity Strength (1-RM) and Power Measures for Total Sample

	Whey	Control	Point Estimates	P Value
	(N = 42)	(N = 38)	(95% CI)*	Time
<i>1-RM (N)</i>				
Double leg press				<.0001
Baseline	1223 ± 380	1256 ± 461	58 (-87,202)	
Six months	1483 ± 517	1465 ± 528		
Unilateral right knee extension				<.0001
Baseline	286 ± 115	297 ± 145	10 (-31,52)	
Six months	378 ± 119	376 ± 172		
Unilateral left knee extension				<.0001
Baseline	259 ± 132	290 ± 127	37 (-37,111)	
Six months	386 ± 212	373 ± 158		
<i>Peak power 40% (W)</i>				
Double leg press				<.0001
Baseline	404 ± 162	443 ± 261	53 (-33,140)	
Six months	569 ± 256	549 ± 266		
Unilateral right knee extension				<.0001
Baseline	108 ± 47	113 ± 61	15 (1,29)	
Six months	140 ± 53	132 ± 64		
Unilateral left knee extension				<.0001
Baseline	94 ± 47	109 ± 48	15 (1,29)	
Six months	131 ± 53	131 ± 61		
<i>Peak power 70% (W)</i>				
Double leg press				<.0001
Baseline	428 ± 192	468 ± 257	61 (-16,137)	
Six months	592 ± 235	567 ± 293		
Unilateral right knee extension				<.0001
Baseline	126 ± 58	135 ± 73	27 (9,45)	
Six months	161 ± 68	146 ± 68		
Unilateral left knee extension				<.0001
Baseline	111 ± 56	128 ± 53	30 (12,47)	
Six months	151 ± 66	139 ± 67		

Note: 1-RM = one repetition maximum.

*Mean change whey (6 month less baseline) minus change in control and the corresponding 95% CI.

Table 5. Physical Performance Measures for Total Sample

Physical Function	Whey	Control	Point Estimates	P Value
	(N = 42)	(N = 38)	(95% CI)*	Time
Stair-climb time (s)				.03
Baseline	7.7 + 4.2	8.5 + 4.6	0.3 (-1.1,1.8)	
Six months	7.1 + 3.9	7.0 + 3.2		
Chair-rise time (s; 10×)				.0001
Baseline	31.8 + 8.5	33.6 + 16.7	-1.9 (-5.2,1.4)	
Six months	24.9 + 6.9	26.8 + 5.9		
SPPB score				<.0001
Baseline	8.5 + 1.1	8.4 + 1.7	0.21 (-0.41,0.83)	
Six months	10.3 + 1.5	10.0 + 1.8		
Four hundred-meter walk (gait speed; m/s)				.13
Baseline	1.1 + 0.2	1.0 + 0.2	0.08 (-0.02,0.19)	
Six months	1.1 + 0.2	1.0 + 0.2		

*Mean change whey (6 month less baseline) minus change in control, and the corresponding 95% CI.

make comparisons between studies difficult. More importantly, most studies have examined healthy older adults with limited data on mobility-limited older adults (15), and where nutritional and not specifically protein supplementation was a focus (19).

Recent reports suggest that MPS is saturable in response to protein supplementation and overload individually. Cuthbertson et al. (27) observed a dose-response for amino acid supplementation with no added gains in MPS following supplementation exceeding 20 and 10 g in young and

old, respectively. In an investigation on younger adults, 20 g of protein supplementation did not augment the effects of RT on MPS (28). The lack of MPS augmentation following 20 g protein supplementation as reported in younger adults may be applicable to older adults also undergoing RT and protein supplementation simultaneously, regardless of physical functional status. Conversely, other observations indicate that at least 40 g of protein per serving may be required to optimally augment MPS in older adults (29). We acknowledge that distributing the supplement into two 20 g

servings per day instead of a 40-g bolus may have blunted the optimal effects on skeletal muscle growth. In addition, the leucine content of WPC in this study may have been inadequate. Katsanos et al. (11) recently observed that a higher amount of leucine is needed for MPS in older relative to younger adults.

Although, a total of 40 g per day of WPC was provided in this study, the average increase in total protein intake when supplement adherence and dietary intake of protein was accounted for was 18 g per day in the WPC group. This was a result of the total dietary energy intake being reduced by approximately 180 kcal per day and adherence to the WPC supplement being approximately 72%. These data suggest that the supplemental WPC was used as a “partial” meal replacement and reduced voluntary food intake in this population. This is in contrast to the study of Fiatarone et al. (19) where a daily nutritional supplement had an isocaloric effect on voluntary food intake completely equivalent to the energy content of the supplement and which appeared to attenuate the influence of the supplement on exercise-induced changes in muscle mass and strength in institutionalized older adults. Despite previous studies examining the acute administration of dietary protein that have shown maximal stimulation of MPS with 40 g of high-quality protein, the results of this study suggest that chronic administration of protein at these dose levels may be difficult as they may suppress energy and protein intake from other dietary sources. Although this lower-than-expected increase in the protein intake observed in the WPC may have attenuated the difference in response between WPC and control, this does not appear to be likely as there were no differences even in the “completer” analysis of participants with the highest adherence.

The dose of RT and session attendance was similar or better than previous exercise training studies in physical functionally impaired older adults (21,26,30). Adherence to the nutritional supplements was similar in both groups and virtually identical between PABA recovery and return of empty packets suggesting self-report of supplement consumption in this population is an acceptable means of tracking supplement adherence. Furthermore, clinically meaningful changes in physical function were reported in a number of the measures in this study suggesting the powerful impact of high-intensity RT in this population (31,32).

We acknowledge there are some limitations in the use of self-report of dietary intake to estimate total energy and protein intake in this study. Participants may have under-reported their dietary intake or even changed their intake as a result of participating in this trial. However, these effects are likely to have been balanced across both treatment arms of the study.

In summary, we observed significant increases in lean mass, muscle CSA, strength and power, and physical function following RT coupled with WPC or control in older mobility-limited adults. However, WPC did not significantly improve the response to 6 months of RT in this population. Future examinations on the efficacy of chronic higher doses

of WPC, administered as a single-bolus serving versus multiple servings, or for longer periods of time on changes in lean mass and physical function in this population are warranted.

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SUPPLEMENTARY MATERIAL

Supplementary material can be found at: <http://biomedgerontology.oxfordjournals.org/>.

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