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Randomized control trials

Muscle strength gains during resistance exercise training are attenuated with soy compared with dairy or usual protein intake in older adults: A randomized controlled trial

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SUMMARY

Background & aims: Maintenance of muscle mass and strength into older age is critical to maintain health. The aim was to determine whether increased dairy or soy protein intake combined with resistance training enhanced strength gains in older adults.
Methods: 179 healthy older adults (age 61.5 ± 7.4 yrs, BMI 27.6 ± 3.6 kg/m^2) performed resistance training three times per week for 12 weeks and were randomized to one of three eucaloric dietary treatments which delivered >20 g of protein at each main meal or immediately after resistance training: high dairy protein (HP-D, >1.2 g of protein/kg body weight/d; ~27 g/d dairy protein); high soy protein (HP–S, >1.2 g of protein/kg body weight/d; ~27 g/d soy protein); usual protein intake (UP, <1.2 g of protein/kg body weight/d). Muscle strength, body composition, physical function and quality of life were assessed at baseline and 12 weeks. Treatments effects were analyzed using two-way ANOVA.
Results: 83 participants completed the intervention per protocol (HP-D = 34, HP-S = 26, UP = 23). Protein intake was higher in HP-D and HP-S compared with UP (HP-D 1.41 ± 0.14 g/kg/d, HP-S 1.42 ± 0.61 g/kg/d, UP 1.10 ± 0.10 g/kg/d; $P < 0.001$ treatment effect). Strength increased less in HP-S compared with HP-D and UP (HP-D 92.1 ± 40.8%, HP-S 63.0 ± 23.8%,UP 92.3 ± 35.4%; $P = 0.002$ treatment effect). Lean mass, physical function and mental health scores increased and fat mass decreased ($P \leq 0.006$), with no treatment effect ($P > 0.06$).
Conclusions: Increased soy protein intake attenuated gains in muscle strength during resistance training in older adults compared with increased intake of dairy protein or usual protein intake.
Clinical Trial Registration: ACTRN12612000177853 www.anzctr.org.au.

1. Introduction

The world's population is aging, with the number of people over 60 yr expected to more than double from 841 million in 2012 to more than 2 billion in 2050 [1], bringing profound implications for many aspects of life. One of the most visible signs of aging is the loss of skeletal muscle mass and strength, which leads to decrements in physical function and may predispose to disability [2]. To reduce disability into older age, it is important to develop strategies that promote maintenance of lean tissue mass, strength and physical function in older adults.

Resistance training is widely recommended for maintaining lean tissue mass and strength in older adults [2]. However, these gains may be potentiated through the application of appropriate nutritional strategies and in particular increased protein intake. A recent meta-analysis reported ~35% greater increases in muscle mass and strength are achieved in older adults undertaking resistance training who consumed at least 1.2 g/kg of body weight/d of protein through supplementation or diet compared with controls (non-protein group, lower protein diet or exercise training with no nutrition co-intervention) [3]. Protein quality or source may further influence the magnitude of exercise training effect, with dairy protein eliciting greater stimulation of muscle protein synthesis

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post-exercise [4] and greater increases in lean mass [5] compared with other protein sources (i.e. soy) in young healthy males. Compared with young adults, the muscle protein synthesis response to resistance exercise [6,7] and protein intake [8] may be blunted in older adults, resulting in higher protein doses (>20 g) being required to stimulate an increase [9].

The aim of the current study was to evaluate whether, when protein intake was at least 20 g at each meal, the consumption of a eucaloric high protein diet rich in dairy protein would provide greater increases in muscle strength, lean mass and physical function compared with either an isocaloric diet representative of the typical Australian dietary protein intake (i.e. ~1.1 g/kg/d [10]) or an isocaloric diet high in non-dairy (i.e. soy) protein in older adults undertaking a program of resistance training.

2. Materials and methods

2.1. Participants

One hundred and ninety two older adults (age, 50–79 yr; BMI, 20–35 kg/m^2) were recruited by public advertisement. Participants were included if they were physically active but not engaged in formal exercise (not participating in >2 x 30 min sessions of moderate to vigorous aerobic exercise or one moderate intensity resistance exercise session per week). If on medication the dose must have been stable for at least 3 months. Participants were excluded if they were intolerant/allergic to lactose or bovine milk protein, on a weight reducing diet, pregnant or lactating, current or recent (6 months) smoker, current or recent (3 months) use of testosterone therapy, previously diagnosed with diabetes, proteinuria, a malignancy, diagnosed with or taking medication for a thyroid condition, or had uncontrolled hypertension (resting blood pressure >160/100 mmHg), untreated depression, a history of metabolic disease, heavy alcohol consumption (>5 drinks/day) or were unable to limit alcohol consumption for study duration. Participants attended a medical screening to ensure they were free from cardiac abnormalities, musculoskeletal injury, joint or peripheral vascular disease (such as hip arthritis, foot and ankle problems or pain) and any other medical condition that would limit participation in the exercise intervention, ability to comply with the dietary requirements, or expose them to risk. The study recruitment and intervention were conducted until the planned sample size was reached in 2 cohorts (recruitment April to July 2012 and January to April 2013; intervention May to October 2012 and March to September 2013). All experimental procedures were approved by and conducted in accordance with the ethical standards of the Human Research Ethics Committees of the University of South Australia and Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the trial was registered on the Australian and New Zealand Clinical Trials Register (ACTRN12612000177853). All participants provided written informed consent prior to study participation.

2.2. Study design

All participants undertook a resistance training program for 12 weeks and were randomized to one of three experimental diets: a high dairy protein diet (HP-D), a high non-dairy (soy) protein diet (HP–S) or a usual protein diet (UP). Randomization was via minimization [11] based on body mass index, age and gender, conducted by a researcher independent to treatment implementation and outcome assessments. Participants were asked to maintain their background physical activity levels (expect for the prescribed study exercise program) and medications constant during the study. Participants attended the Sansom Institute for Health Research Clinical Trial Facility at the University of South Australia for assessments at Week 0 and Week 12 after an overnight fast. Researchers conducting outcome assessments were blinded to the participants' treatment allocations.

2.3. Dietary intervention

The three experimental diets were isocaloric and low-fat (30% fat, <8% saturated fat) and aimed to maintain energy balance. The diets provided ~1 g/kg of body weight/d of dietary protein, primarily from lean meat sources. HP-D providing an additional ~27 g per day of dairy-based protein in the form of a shake (475 g Devondale Smart reduced fat milk, 200 g Nestle Soleil diet no fat yoghurt and 20 ml Bickfords vanilla milk mix syrup), and HP-S providing an additional ~27 g of soy protein in the form of a shake (300 g So Good reduced fat soy milk, 100 g Kingland soy yoghurt, 20 g Nature's Way instant natural protein powder and 15 g poly-joule). Energy was matched for UP by providing additional carbohydrate foods (500 ml orange juice, 13 g poly-joule and 2 Arnotts YoYo sweet biscuits). The distribution of protein intake within each dietary pattern was spread evenly across the three main meals to achieve a protein intake at each meal of >20 g, which is consistent with current recommendations for optimizing muscle protein synthesis in older adults [12–14]. On days when participants performed resistance exercise training the appropriate additional foods were consumed immediately after training that took the place of the main meal that would have been consumed at that time of day.

The dietary patterns were prescribed as specific quantities of food, individualized for the participant's energy requirements to achieve weight maintenance and presented in a checklist format that was completed daily. Alcohol intake was limited to <7 standard drinks per week based on individualized energy requirements. Participants attended individual dietary counseling visits at the Clinical Research Unit of CSIRO – Food and Nutrition at baseline and every two weeks for the duration of the study to ensure compliance with the diet and maintenance of weight. To facilitate compliance, participants were supplied with key foods specific to their allocated diet for the duration of the study. Energy and macronutrient intakes from daily quantitative food checklists were analyzed using the Foodworks program (Xyris software, Brisbane, 2009) with the Australian Nutrient database to monitor food intake and dietary compliance. Twenty four hr urine samples were collected at baseline and after 12 weeks for analysis of urinary urea and creatinine as an objective marker of the level of protein intake on an automated analyzer (Konelab 20XT, Thermo Fisher Scientific Inc, USA) using commercially available kits.

2.4. Exercise intervention

All participants undertook a progressive overload, whole body resistance training program three days per week on non-consecutive days. The program consisted of five exercises performed on weight stack pin loaded machines: leg press, chest press, knee extension, lat pull down and leg curl, as well as seated bent knee hip flexions. For the machine-based exercises the training load was progressive and started with one set of eight reps at a resistance equivalent to the participant's 8 repetition maximum (RM; maximum weight lifted for eight repetitions) and resistance was maintained until participants could perform three sets of 12 repetitions. The resistance was then increased so only eight repetitions could be performed again in the first set, and this resistance was maintained until participants could again perform three sets of 12 repetitions. This pattern of altering resistance and repetitions

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continued throughout the study period to ensure a progressive increase in training load. For the seated bent knee hip flexions participants gradually increased the number of repetitions and sets throughout the training period until they could perform two sets of 20 repetitions, and this was then maintained for the remainder of the study period. All exercise training was completed in the research gymnasium at the University of South Australia under the supervision of gymnasium staff. The number of sets, repetitions and weight lifted during each training session were recorded in a training log, which was analyzed to quantify progression in training loads and assess compliance.

2.5. Outcome assessments

Muscle strength was assessed using handgrip, isokinetic dynamometry and 8RM. Individuals 8RM was measured for five of the exercises from the training program (leg press, chest press, leg extension, lat pull down and leg curl) and summed to calculate total 8RM. Dominant handgrip strength was measured using the protocol of the American Society for Hand Therapists [15] with an adjustable, hydraulic handgrip dynamometer (JAMAR, Model 5030J1, Sammons Preston Roylan, Bolingbrook, IL, USA). Isometric strength of the knee extensor muscles of the right leg was assessed using an isokinetic dynamometer (Biodex System 4, Biodex Medical Systems Inc., New York, USA) with data sampled at 1000 Hz using a data acquisition system (PowerLab 16/30, ADInstruments, Bella Vista, NSW). The knee was flexed at 90° and participants were verbally encouraged to perform a maximal voluntary contraction. For handgrip and isometric strength, the highest value achieved after three attempts was used for analysis.

Height and weight were measured with participants lightly clothed using a wall-mounted stadiometer (Seca, Hamburg, Germany) and electronic digital scale (Tanita Ultimate Scale, Tanita Corp, Tokyo, Japan) respectively, and BMI was calculated. Waist circumference was measured according to the protocols of the International Society for Anthropometry and Kinanthropometry [16]. Lean tissue mass and body fat were assessed by DXA (Lunar Prodigy, General Electric, Madison WI, USA). Physical function was assessed using the 6 min walk test [17]. Quality of life was assessed using the self-report short-form 36 health survey (SF-36v2), which was scored using Health Outcomes Scoring Software. The SF-36v2 measures eight domains of health-related quality of life and these were aggregated into Physical Component Summary (physical health) and Mental Component Summary (mental health) scores [18].

2.6. Statistical methods

Data were analyzed using SPSS Statistics 21 (IBM Corporation, Armonk, NY) with a significance of $P < 0.05$. Data are presented as mean ± SD. Data were tested for normality, and non-normally distributed data were log transformed prior to analysis (percent change in total 8RM, isometric knee strength, total 8RM, leg press 8RM, chest press 8RM, knee extension 8RM, weight, total fat, polyunsaturated fat, monounsaturated fat and carbohydrates) or if transformation did not achieve normality, non-parametric analyses were used (lat pull down 8RM, leg curl 8RM, handgrip, lean mass, quality of life, energy, protein [from background diet, additional protein foods provided to HP-D and HP-S, dairy and soy protein consumed], saturated fat and alcohol). Baseline characteristics and dietary intakes were compared between groups using one-way ANOVA, Kruskal–Wallis test or chi-squared (gender). The primary outcome was the difference between groups in percentage change in 8RM strength by 12 weeks. Percentage change was used to account for differences in absolute strength gains between genders. These data were compared using one-way ANOVA, with Tukey's HSD to identify differences between means where a significant main effect was determined. For the primary outcome there was no differences between genders ($P = 0.7$), or age tertiles ($P = 0.7$) so participants of all ages and both genders were pooled for analysis. For other outcomes the effects of the treatments on the dependent variables and their interactions over time were analyzed using two-way repeated measures ANOVA with treatment and time the between and within group factors respectively. Where a statistically significant main effect was found, post-hoc comparison of means was undertaken using Tukey's HSD. Analysis of covariance was used to compare the changes in different treatments while controlling for baseline values and where a statistically significant diet effect was found, post-hoc comparisons were undertaken using Bonferonni correction. For non-normally distributed data the Wilcoxon signed-rank test was used to compare baseline and week 12 data to determine any time effect and Kruskal–Wallis test was used to analyze change values to determine if there was any difference between the diets. If there was a significant diet effect, post hoc analysis was performed using Mann–Whitney U tests. Linear regression was used to assess relationships between variables.

A per protocol analysis was performed using only participants that were compliant with the diet (average protein intake was at least 1.2 g/kg body weight/day for HP-D and HP-S and less than 1.2 g/kg body weight/day for UP) and exercise program (completed at least 70% of exercise sessions and followed the prescribed training program) in order to evaluate the efficacy of complying with the diet and exercise protocols. An intention to treat analysis was also conducted and the results demonstrated a similar pattern to the per protocol analysis (data not shown). Sample size calculations were based on an anticipated 10% greater increase in total 8RM strength in HP-D [5], with a 15% standard deviation for changes in muscle strength after 3 months [19]. It was estimated that to achieve 80% power with an α level of 0.05 would require 37 participants per treatment group to complete the study. One hundred and twenty five participants completed the study (HP-D = 41, HP-S = 44, UP = 40).

3. Results

One hundred and twenty five participants completed the study and 83 were compliant with the diet and exercise intervention (HP-D = 34, HP-S = 26, UP = 23; Fig. 1). Baseline characteristics were similar between groups for participants who commenced the intervention ($P > 0.9$; Table 1). 36% ($n = 67$) of participants withdrew prior to ($n = 13$) or during the intervention ($n = 54$) and this was not different between treatments ($P = 0.5$). Compliance with the intakes of the additional dairy, soy and carbohydrate foods for the relevant treatments for those that were deemed to meet dietary compliance was not different between groups (HP-D, 97.0 ± 3.5%; HP-S, 98.1 ± 3.1%; UP, 98.4 ± 2.2%; $P = 0.3$). Exercise session attendance was high and did not differ between treatment groups for those that were compliant to the study protocol (HP-D, 91.4 ± 7.3%; HP-S, 93.2 ± 6.8%; UP, 92.9 ± 7.4%; $P = 0.6$).

Changes in strength outcomes are reported in Table 2. Overall the 8RMs improved ($P < 0.001$), with the majority increasing to a greater extent in HP-D and UP compared to HP-S, such that the percent change in total 8RM was significantly greater in HP-D and UP compared to HP-S (HP-D, 92.1 ± 40.8%; HP-S, 63.0 ± 23.8%; UP, 92.3 ± 35.4%; $P = 0.002$). There was no difference between HP-D and UP ($P = 0.99$). The percent improvement in leg press 8RM was greater in HP-D and UP compared with HP-S (HP-D, 136.8 ± 88.2%; HP-S, 64.8 ± 35.2%; UP, 135.0 ± 62.0%; $P < 0.001$) and the percent improvement in lat pull down 8RM was greater in UP

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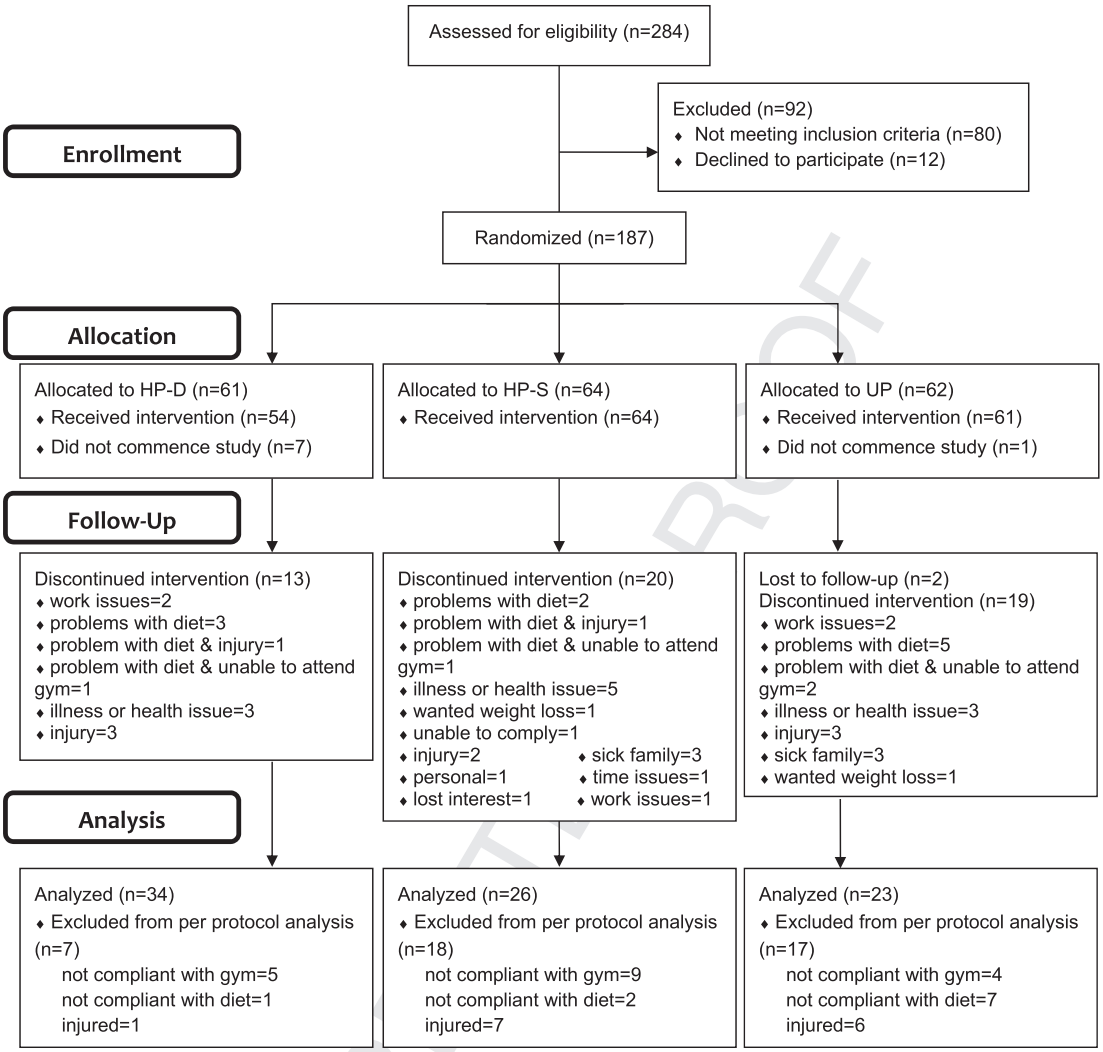

Fig. 1. CONSORT diagram (HP-D, high dairy protein diet; HP-S, high soy protein diet; UP, usual protein diet).

compared with HP-D and was not different from HP-S (HP-D, 24.6 ± 12.2%; HP-S, 28.2 ± 11.7%; UP, 35.1 ± 17.0%; P = 0.01). There were no differences between diets for changes in chest press, knee extension or leg curl 8RMs (P ≥ 0.2). Isometric knee extensor strength improved (P < 0.001), with a non-significant trend for a smaller increase in HP-S compared with the other treatments (P = 0.08). Handgrip strength increased significantly (P < 0.001), with no difference between groups (P = 0.6). There was no difference in the total training load lifted over the 12 weeks between the groups (HP-D, 210,976 ± 82,651 kg; HP-S, 231,890 ± 109,344 kg; UP, 203,160 ± 52,314; P = 0.8).

Table 1
Baseline characteristics of participants commencing the intervention.

	HP−D (n = 54)	HP−S (n = 64)	UP (n = 61)
Age (yrs)	61.3 ± 6.9	61.7 ± 8.3	61.5 ± 6.9
Weight (kg)	79.4 ± 15.2	79.0 ± 13.3	77.6 ± 12.4
BMI (kg/m^2)	27.7 ± 3.9	27.5 ± 3.7	27.6 ± 3.3
M [n(%)]	25 (46%)	29 (45%)	27 (44%)
F (n)	29	35	34

Data are mean ± SD, HP-D, high dairy protein diet; HP-S, high soy protein diet; UP, usual protein diet.
No differences between diets (P > 0.9).

Weight, waist circumference and total body fat decreased and lean mass and the distance covered during the 6 min walk test increased significantly increased (P < 0.001), with no difference between diets (P ≥ 0.1; Table 3). For the quality of life questionnaire outcomes, the mental health score improved (P = 0.001; Table 3) and the physical health score did not change (P = 0.2), with no diet effect (P > 0.4).

Average daily dietary intakes are reported in Table 4. Total energy and total and monounsaturated fat intakes were not different between groups (P ≤ 0.08). Saturated fat and polyunsaturated fat intakes were higher and lower respectively in HP-D and UP compared with HP-S (P < 0.03). Carbohydrate (P = 0.07) and alcohol (P = 0.9) intakes were not different between treatments. Absolute protein intake (g) and relative protein intake (per kg body weight) were different (P < 0.001), with HP-D and HP-S greater than UP (P < 0.001). The amount of dairy protein in the diet was significantly greater in HP-D compared with both HP-S and UP (P < 0.001). The amount of non-dairy protein in the diet was significantly greater in HP-S compared with both HP-D and UP (P < 0.001).

Urinary urea:creatinine ratio changed significantly between diets (P = 0.03), with HP-D and HP-S increasing compared with UP (HP-D, 5.6 ± 7.7; HP-S, 7.9 ± 9.2; UP, -7.5 ± 7.8; P < 0.001). Change in urinary urea:creatinine ratio was positively associated with the

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Table 2
Muscle strength values at baseline (Week 0) and after the intervention (Week 12) for participants compliant with the study protocol.

	High dairy protein (n = 34)			High soy protein (n = 26)			Usual protein (n = 23)		
	Week 0	Week 12	Change	Week 0	Week 12	Change	Week 0	Week 12	Change
Isometric knee extensor strength (Nm)*	132.3 ± 54.9	157.8 ± 62.2	25.5 ± 22.1	142.4 ± 61.6	160.8 ± 61.7	18.4 ± 18.6	122.3 ± 43.6	152.8 ± 50.1	30.5 ± 24.8
Handgrip strength (kg)*	35.0 ± 10.3	36.0 ± 10.7	1.0 ± 3.1	34.0 ± 10.9	35.7 ± 10.1	1.6 ± 3.1	33.7 ± 9.6	35.7 ± 9.3	2.0 ± 3.9
Leg press 8RM (kg)*‡	55.0 ± 24.3[a]	120.2 ± 42.5	65.2 ± 30.3[a]	77.3 ± 41.1[b]	124.6 ± 67.7	47.4 ± 34.1[b]	56.6 ± 22.8[a,b]	122.8 ± 31.1	66.3 ± 25.4[a]
Chest press 8RM (kg)*	25.6 ± 13.0	43.0 ± 16.4	17.4 ± 6.7	28.7 ± 15.2	46.2 ± 23.8	17.4 ± 11.1	23.3 ± 9.8	36.6 ± 12.5	13.3 ± 4.5
Knee extension 8RM (kg)*	20.9 ± 10.9	50.3 ± 18.7	29.4 ± 14.1	25.3 ± 15.0	48.3 ± 21.5	23.0 ± 11.7	22.7 ± 11.0	48.3 ± 16.3	25.6 ± 10.5
Lat pull down 8RM (kg)*	40.8 ± 10.1	50.9 ± 13.5	10.1 ± 5.3	39.5 ± 10.2	50.8 ± 14.9	11.3 ± 6.4	36.5 ± 6.9	49.0 ± 9.6	12.5 ± 5.6
Leg curl 8RM (kg)*	10.5 ± 4.5	24.4 ± 12.0	13.9 ± 9.0	11.6 ± 8.5	23.6 ± 12.9	12.0 ± 6.3	10.3 ± 5.9	21.7 ± 8.8	11.3 ± 5.5
Total 8RM (kg)*‡	148.9 ± 50.6	280.2 ± 87.7	131.3 ± 54.2[a]	168.6 ± 78.5	270.7 ± 121.6	102.1 ± 50.7[b]	147.0 ± 49.7	273.0 ± 67.5	126.1 ± 41.3[a]

Data are mean ± SD; 8RM, maximum weight lifted for eight repetitions.
*improved at Week 12 ($P < 0.001$), different letters reflect significant differences between diets for that time point, no letters reflect there were no significant differences between diets; ‡ANCOVA with baseline value as covariate used to compare differences between diets.

Table 3
Body composition, physical function and quality of life values at baseline (Week 0) and after the intervention (Week 12) for participants compliant with the study.

	High dairy protein (n = 34)			High soy protein (n = 26)			Usual protein (n = 23)		
	Week 0	Week 12	Change	Week 0	Week 12	Change	Week 0	Week 12	Change
Weight (kg)[a]	77.7 ± 15.6	76.8 ± 15.3	−1.0 ± 1.5	75.8 ± 12.6	74.6 ± 12.7	−1.2 ± 1.3	74.9 ± 10.2	73.9 ± 10.5	−1.0 ± 1.0
Waist circumference (cm)[a]	93.2 ± 11.3	91.2 ± 11.5	−2.0 ± 2.4	90.5 ± 11.9	88.0 ± 11.7	−2.5 ± 2.6	94.2 ± 10.7	91.7 ± 11.4	−2.6 ± 2.3
Total Body % Body Fat[a]	36.1 ± 7.5	34.0 ± 8.1	−2.2 ± 1.7	35.0 ± 8.1	32.0 ± 8.3	−3.0 ± 1.7	37.1 ± 8.2	35.1 ± 9.3	−2.0 ± 1.5
Total Body Fat Mass (kg)[a]	28.2 ± 8.2	26.2 ± 8.3	−2.0 ± 1.6	26.4 ± 6.7	23.8 ± 7.0	−2.6 ± 1.4	27.8 ± 7.5	26.0 ± 8.4	−1.8 ± 1.3
Total Body Lean Mass (kg)[a]	49.6 ± 11.0	50.6 ± 11.2	1.0 ± 1.0	49.4 ± 11.2	50.8 ± 11.2	1.4 ± 1.2	47.1 ± 9.1	47.9 ± 9.7	0.8 ± 1.1
Six minute walk test distance (m)[a]	604.6 ± 56.5	641.2 ± 61.3	36.5 ± 35.9	609.5 ± 86.2	635.6 ± 87.6	25.1 ± 35.5	584.5 ± 83.3	603.7 ± 86.2	19.2 ± 54.1
Physical health score	55.3 ± 3.5	55.3 ± 3.4	−0.01 ± 3.6	54.3 ± 4.3	54.4 ± 5.5	0.07 ± 6.5	54.0 ± 4.5	55.5 ± 4.0	1.5 ± 3.5
Mental health score[a]	54.9 ± 4.5	56.8 ± 3.4	2.0 ± 4.3	56.5 ± 3.7	57.8 ± 3.7	1.4 ± 3.2	54.6 ± 6.5	55.7 ± 5.1	1.1 ± 4.3

Data are mean ± SD.
[a] Improved at Week 12 ($P \leq 0.001$), there were no differences between diets ($P \geq 0.1$).

average daily intake of total protein ($r = 0.50$, $P < 0.001$), dairy protein in grams ($r = 0.29$, $P = 0.02$), and non-dairy protein in grams ($r = 0.36$, $P = 0.005$).

No serious injuries or adverse events were associated with the diet or exercise program. Five participants withdrew due to joint soreness related to the exercise training program (HP-D = 2, HP-S = 2, UP = 1). A further 33 participants reported joint pain or muscle soreness but continued with a modified exercise program. Three participants in the HP-D treatment experienced difficulties in consuming the dairy foods, reporting stomach pains, bloating and diarrhea, possibly due to previously unrecognized lactose intolerance. The soy foods provided for the HP-S diet were not tolerated by one participant, and four participants had difficulties consuming the orange juice supplement from the UP diet (reflux; sore throat and spasms; diarrhea and nausea). All eight of these participants that experienced difficulty consuming the foods withdrew from the study.

Table 4
Average dietary intake during the 12 week study period.

	High protein - dairy (n = 34)	High protein - soy (n = 26)	Usual protein (n = 23)
Energy (kJ)	8384 ± 1440	8091 ± 1304	8000 ± 1070
Fat (g)	56.6 ± 13.0	53.9 ± 10.8	49.6 ± 6.1
Saturated Fat (g)	16.7 ± 3.1[a]	13.0 ± 2.9[b]	15.1 ± 2.8[a]
Polyunsaturated Fat (g)	8.6 ± 3.2[a]	10.2 ± 2.9[b]	7.5 ± 1.6[a]
Monounsaturated Fat (g)	25.1 ± 7.3	24.6 ± 5.6	21.4 ± 4.3
Carbohydrates (g)	242.6 ± 48.3	232.8 ± 45.4	261.9 ± 46.9
Alcohol (g)	4.7 ± 4.1	4.7 ± 4.1	4.6 ± 3.5
Protein (g)	109.6 ± 15.2[a]	108.8 ± 10.9[a]	80.3 ± 9.8[b]
From background diet (g)	82.7 ± 15.2	81.3 ± 10.9	75.9 ± 9.7
From supplement (g)	26.9 ± 0.2[a]	27.6 ± 0.1[b]	4.4 ± 0.1[c]
Dairy protein (g)	36.5 ± 0.5[a]	9.9 ± 0.4[b]	10.0 ± 1.2[b]
Non-dairy protein (g)	74.0 ± 15.2[a]	99.0 ± 11.7[b]	68.2 ± 7.4[a]
Protein (g/kg body weight)	1.42 ± 0.14[a]	1.45 ± 0.14[a]	1.08 ± 0.05[b]
From background diet (g/kg body weight)	1.06 ± 0.10[a,b]	1.08 ± 0.09[a]	1.02 ± 0.05[b]

Data are mean ± SD; different letters reflect significant differences; no letters reflect there were no significant differences between diets.

4. Discussion

This study showed that in healthy older community dwelling adults undertaking 12 weeks of progressive resistance training exercise, the intake of additional protein (dairy or soy) compared to usual protein intake did not provide any additional benefit for improvements in strength, body composition, physical function, or quality of life. Moreover, it was determined that increased soy protein intake attenuated improvements in strength.

The absence of any greater increases in strength or lean body mass with a higher dairy protein intake contrasts with the findings of Hartman et al. [5]. This study showed that consumption of dairy protein (~18 g) in the hour immediately after training during 12 weeks of progressive resistance training resulted in greater increases in lean mass and tended to increase strength more compared with soy protein supplementation or a control diet in young men. In that study, the soy and dairy protein groups consumed 1.7–1.8 g/kg/day of protein, which was similar to the control group (1.6–1.7 g/kg/day), indicating the observed effects were due to protein quality, rather than quantity. A recent meta-analysis indicated timing of protein intake in close proximity to exercise training had no effect on muscle strength adaptations or hypertrophy, with total daily protein intake being the best predictor of hypertrophy response [20]. This was confirmed in another recent meta-analysis which reported greater increases in strength and

lean mass in younger and older adults following an average of 50 g/day protein supplementation in addition to a usual background dietary protein intake of ~1.2 g/kg/day during resistance training [3]. The similarity of the protein intakes in the background diet used in the present study suggests that the lack of a significant effect of an increased protein intake with the HP-D and HP-S treatments on lean tissue mass or strength compared with UP may have been due to the relatively low protein content of the additional protein foods consumed (i.e. ~27 g/day) that equated to only half of the additional 50 g/day reported to provide a benefit in the meta-analysis, and may have resulted in too small a differential in protein intake between the HP-D and HP-S treatments compared with UP. However, in the present study the practicality to increase the protein intake was somewhat limited by the desire to use whole foods rather than concentrated protein supplement powders.

Alternatively, rather than insufficient protein supplementation being responsible for the lack of any greater improvements in strength or lean tissue mass, it is possible that distributing the protein intake to achieve >20 g at each main meal across all treatments groups might have provided optimal stimulation of lean tissue mass and strength even with the lower protein intake of the UP diet. Similarly to the present study, Leenders et al. [21] showed no augmentation of increases in muscle strength, lean mass or markers of muscle hypertrophy or functional capacity in healthy older adults (69 yr) during 24 weeks of resistance training when the background protein intake of 1.1–1.2 g/kg was increased to 1.3–1.4 g/kg with protein supplementation, and a protein intake of ~25 g was delivered across all main meals. The authors proposed that the absence of any additional benefits of protein supplementation was due to sufficient dietary protein requirements being met by the background protein intake when the intake was spread evenly across the main meals of the day to maximally stimulate muscle protein synthesis.

In contrast, Daly et al. [22] showed in older women (73 yr, range 60–90 yr) undertaking a program of moderate intensity progressive resistance training twice per week for 4 months, that a high protein intake (1.3 g/kg/d) achieved through an increased intake of lean red meat at lunch and dinner (resulting in a skewed protein intake distribution across the day) achieved an 18% greater increase in lean tissue mass and strength compared with a lower protein intake (1.1 g/kg/d). In this study, the high protein intake group experienced increases in lean tissue mass of 0.6 kg and increases in knee extensor strength of 87%. These increases were markedly lower than the 0.9 kg increase in lean tissue mass and the ~130% increase in knee extension strength observed across treatment groups in the present study. This might have been due to the relatively high intensity of the resistance training program used in the present study, or the higher exercise stimulus combined with the even distribution of protein intake across the day. The finding of similar increases in strength in UP and HP-D suggests that the even distribution of protein intake might have promoted optimal stimulation of muscle protein synthesis that maximized lean tissue mass and strength adaptations even at the lower level of protein intake that was provided for UP.

Despite the absence of any greater increases in strength or lean mass following increased dairy protein consumption in HP-D compared with UP, it appeared that strength increases were attenuated by the intake of soy protein. Several studies have shown that the ingestion of soy protein promotes smaller increases in muscle protein synthesis and muscle protein accretion compared with the ingestion of dairy protein [13,23]. The attenuated muscle protein synthesis response has been attributed primarily to amino acid profile differences with soy being less rich in leucine, a key amino acid that stimulates muscle protein synthesis [13,24]. However, in the present study HP-S had attenuated muscle strength gains compared with UP and HP-D, suggesting a smaller increase in contractile protein content in the muscles being trained. Both HP-D and UP received similar protein intakes in the background diet, which appeared to be sufficient to support muscle anabolism and strength gains; reflected by the similar increases in strength between HP-D and UP. However, despite HP-S also receiving a slightly higher protein intake in the background diet compared with UP the increase in strength was attenuated. It is unlikely that this was due to a lesser quality of the soy protein consumed as the protein in the background diet should have been sufficient to support muscle adaptation, as it did for those assigned to the UP treatment. Instead, it is more likely that the attenuation of the strength increase in the HP-S group was due to some effect of the soy inhibiting the increase in strength. Soy foods not only contain soy protein, but also contain isoflavones, which exhibit estrogenic properties [25]. A recent study demonstrated that 14 days of soy protein supplementation in resistance trained young men during training reduced serum testosterone concentrations in the first 30 min post-exercise compared with whey protein or a carbohydrate control [26]. It was proposed that this blunted serum testosterone response might reduce the anabolic response in skeletal muscle, thus attenuating the accretion of contractile protein and muscle strength gains. This may explain the attenuated increase in strength gains observed in the HP-S group in the present study. However, blood samples were not collected post-exercise so it is not possible to confirm this hypothesis that should be tested in future investigations.

In summary, when energy intake is isocaloric and protein intake is evenly distributed across the day, an increased intake of dairy protein does not promote greater increases in strength, lean tissue accretion, physical function or quality of life following resistance exercise training in healthy older community dwelling adults. However, strength gains are attenuated by an increased intake of soy foods; an effect that may be mediated by soy isoflavones reducing post-exercise increases in serum testosterone levels. Further studies should be undertaken to confirm this effect of soy foods, and seek to identify the mechanism of action to better inform guidelines related to the most appropriate protein sources to consume in conjunction with resistance exercise training in order to achieve optimal adaptations in strength.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.clnu.2015.01.018.

Statement of authorship

JB, GB and MN designed research; RT conducted research and analyzed data; RT, JB, GB and MN wrote the paper; JB had primary responsibility for final content. All authors read and approved the final manuscript.

Conflict of interest and funding sources

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