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Original citation & hyperlink:
Piri Damaghi, M, Mirzababaei, A, Moradi, S, Daneshzad, E, Tavakoli, A, Clark, CCT & Mirzaei, K 2021, 'Comparison of the Effect of Soy protein and Whey protein on Body Composition: A Meta-Analysis of Randomized Clinical Trials', British Journal of Nutrition.
https://dx.doi.org/10.1017/S0007114521001550

DOI 10.1017/S0007114521001550
ISSN 0007-1145
ESSN 1475-2662

Publisher: Cambridge University Press

Accepted manuscript

Comparison of the Effect of Soy protein and Whey protein on Body Composition: A Meta-Analysis of Randomized Clinical Trials

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Conflict of interests: None

Running title: Comparison of the Effect of soy and whey protein on body composition

This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its DOI

10.1017/S0007114521001550

The British Journal of Nutrition is published by Cambridge University Press on behalf of The Nutrition Society

Abstract:

Background: Essential amino acids (EAAs) promote the process of regulating muscle synthesis. Thus, whey protein that contains higher amounts of EAA can have a considerable effect on modifying muscle synthesis. However, there is insufficient evidence regarding the effect of soy and whey protein supplementation on body composition. Thus, we sought to perform a meta-analysis of published Randomized Clinical Trials that examined the effect of whey protein supplementation and soy protein supplementation on body composition (lean body mass, fat mass, body mass and body fat percentage) in adults.

Methods: We searched PubMed, Scopus, and Google Scholar, up to August 2020, for all relevant published articles assessing soy protein supplementation and whey protein supplementation on body composition parameters. We included all Randomized Clinical Trials that investigated the effect of whey protein supplementation and soy protein supplementation on body composition in adults. Pooled means and standard deviations (SD) were calculated using random-effects models. Subgroup analysis was applied to discern possible sources of heterogeneity.

Results: After excluding non-relevant articles, 10 studies, with 596 participants, remained in this study. We found a significant increase in lean body mass after whey protein supplementation weighted mean difference (WMD: 0.91; 95% CI: 0.15, 1.67. P= 0.019). Subgroup analysis, for whey protein, indicated that there was a significant increase in lean body mass in individuals concomitant to exercise (WMD: 1.24; 95% CI: 0.47, 2.00; P= 0.001). There was a significant increase in lean body mass in individuals who received 12 or less weeks of whey protein (WMD: 1.91; 95% CI: 1.18, 2.63; P<0.0001). We observed no significant change between whey protein supplementation and body mass, fat mass, and body fat percentage. We found no significant change between soy protein supplementation and lean body mass, body mass, fat mass, and body fat percentage. Subgroup analysis for soy protein indicated there was a significant increase in lean body mass in individuals who supplemented for 12 or less weeks with soy protein (WMD: 1.48; 95% CI: 1.07, 1.89; P< 0.0001).

Conclusion: Whey protein supplementation significantly improved body composition via increases in lean body mass, without influencing fat mass, body mass, and body fat percentage.

Keywords: Whey protein, Soy protein, Body composition, Lean body mass, Fat mass, Body mass, Body fat percentage

Introduction

Whey and soy protein, as animal and plant-based sources, respectively, both represent complete proteins [1, 2]. However, there are some differences between these two types of protein, including, amino acid composition, digestion, and absorption. Whey protein, compared to soy, contains a higher amount of essential amino acids (EAAs) per gram and 50% more branched-chain amino acids (BCAAs) [3, 4]; in addition, soy protein is less digestible than whey [5, 6].

Resistance exercise with high protein intake, especially whey, has been shown to elicit a positive effect on muscle protein synthesis [7]. Leucine is an EAA and BCAA that exists in soy and, in greater amounts, whey protein, and plays an important role in stimulating skeletal muscle protein synthesis at rest and following exercise [8-11]. Indeed, this amino acid can affect the mammalian target of the rapamycin (mTOR) signaling pathway related to protein synthesis and therein enable synthesis [12, 13].

Fat mass, particularly visceral adipose tissue, contributes to inflammation in obesity. Enhancing lean body mass can prevent, or at least ameliorate, the increase of fat mass and its consequences [14, 15]. Empirical data indicates that having high-protein meals (30% of total energy intake) during periods of energy restriction, with exercise, especially dairy-source proteins that contain BCAA, can promote greater fat mass loss and lean mass retention [16]. Further, BCAA leucine inhibits adipocyte lipogenesis and stimulates lipolysis; therefore, whey protein that contains high amount of this amino acid, can contribute to fat mass loss and lean body mass retention more than soy [17-19]. Tahavorgar et al, in a 12-week, randomized, double blind clinical trial, in free-living overweight and obese men, indicated that whey protein elicits stronger effects on appetite, anthropometric indicators, and body composition than soy protein [20]. Additionally, a nine-month resistance training and protein supplementation intervention, by Volek and colleagues, demonstrated that lean body mass gains were greater in the group supplementing with whey protein compared to soy protein [21]. On the other hand, in a study by Brown and colleagues, participants supplemented with either soy or whey protein bars during a 9 week resistance training intervention, and there were no significant differences between groups with regards to increases in lean body mass [22].

Inconsistent results from RCTs might be explained by the variegated study designs, dose and duration of intervention, and variety of age groups and genders. An advantage of meta-analysis vs. narrative reviews is the potential to yield less biased summaries of the published findings. Therefore, we sought to conduct a meta-analysis of published RCTs to summarize the evidence on the comparison between whey and soy protein supplementation on body composition among healthy adults, and to identify possible sources of heterogeneity between studies.

Methods

This meta-analysis was conducted according to the meta-analysis of RCT studies in epidemiology Cochrane library guidelines.

Search strategy

All articles were retrieved through PubMed, Scopus, and Google Scholar, up to August 2020, to identify relevant articles. We utilized medical subject headings (MeSH) and non-MeSH keywords. The following terms were used in the electronic search :("body composition"[tiab] OR "fat mass"[tiab] OR "fat percentage"[tiab] OR "body fat"[tiab] OR "lean mass"[tiab] OR "body lean"[tiab] OR "body mass"[tiab] OR weight[tiab] OR "Weight loss"[tiab] OR "weight reduction"[tiab] OR Overweight[tiab] OR Obesity[tiab] OR "body weight"[tiab] OR "body mass index"[tiab] OR BMI[tiab] OR "Visceral adipose tissue"[tiab] OR "adipose tissue"[tiab] OR "Perinephric fat"[tiab] OR "muscle mass"[tiab] OR "Body Composition"[Mesh] OR "Adipose Tissue"[Mesh] OR "Overweight"[Mesh] OR "Adiposity"[Mesh] OR "Body Mass Index"[Mesh] OR "Obesity"[Mesh] OR "Body Weight"[Mesh] OR "Weight Loss"[Mesh] OR "Obesity, Abdominal"[Mesh] OR "Intra-Abdominal Fat"[Mesh] OR "Abdominal Fat"[Mesh]) AND ("soy protein"[tiab] OR "soy"[tiab] OR "soy protein"[Mesh] OR "Soy Bean Proteins"[Mesh] OR "Dietary Soybean Protein"[Mesh] AND "Whey"[tiab] OR "Whey protein"[tiab] OR "Whey"[Mesh] OR "Whey protein"[Mesh]. We had no date and language restriction. To reduce the likelihood of missing any study, the reference lists of all included studies were manually reviewed, and we did not include unpublished data and grey literature, including congress abstracts, thesis, dissertations, and patents.

Inclusion criteria

We included all randomized clinical trials that investigated the effect of soy protein supplementation and whey protein supplementation on body composition in adults (≥ 18 years old). Studies that reported mean ± standard deviation (SD), mean ± standard error (SE), or 95% confidence intervals (CI) for body composition variables, such as lean body mass, fat mass, body mass, and body fat percentage, before and after intervention, in the intervention and placebo group, were included.

Exclusion criteria

We excluded studies if they were observational, letters to the editor, review articles, in vitro studies, case reports, protocol studies, or animal experiments. In addition, studies that had no control group to compare the results with intervention group or had no body composition related data were excluded. Finally, we excluded articles where their study population had diseases that are known to affect body composition.

Study selection

Titles and abstracts of all retrieved articles were evaluated independently by 2 reviewers (MP and AM). Articles that did not meet the eligibility criteria were excluded using a screen form, with a hierarchical approach, based on study design, population, intervention, or outcome. Next, full-texts of eligible articles were retrieved, and subjected to a secondary evaluation by the same reviewers. Any disagreements were discussed and resolved by consensus.

Data extraction

Two independent reviewers (MP and AM) independently extracted data from the included publications, using a standard data extraction form. Data collected from each study included: first author's last name, publication year, country, characteristics of the participant (number, age, sex, health status), study design, type and dose of intervention and placebo, and duration of intervention, mean ± standard deviation and/or changes of the components of body composition, including lean body mass, fat mass, body mass, and body fat percentage. If data were reported as SEs or 95% CI, they were converted to SDs by use of standard formulae.

Quality assessment for individual studies

Two reviewers (MP and AM) assessed the quality of each selected study and the associated risk of bias using the Cochrane Collaboration's tool for quality assessment of randomized controlled trials. The quality assessment tool includes the following items: random sequence generation, allocation concealment, blinding of participants and personnel, and outcome assessment, incomplete outcome data, selective reporting, and other biases.

Statistical analysis

All effect sizes were calculated as mean ± SD of changes in body composition components between intervention and control group. The random-effects model was used to calculate the overall effect size. We examined heterogeneity between studies by the Cochran's Q test and I^2 statistic. To discern heterogeneity between studies, subgroup analyses were conducted based on sex (male/female), exercise (with exercise/without exercise), supplement dose (< 50 or ≥ 50g/day), duration of intervention (< 12 / ≥ 12 weeks), and health status (healthy/overweight or obese). All statistical analyses were conducted using Stata software, version 13, and statistical significance was accepted, *a priori*, at $P<0.05$..

Results

A total of 662 relevant articles were detected in the initial search, of which, 170 were duplicate. The remaining 492 studies were screened based on titles and abstracts. Finally, 55 full-text articles were reviewed in detail, and 10 were included in the final meta-analysis. The reviewing process is shown in **Figure 1.**

10 trials, with 596 subjects, were included, of which, 356 participants were in the intervention and 240 in control group, respectively. Study characteristics are presented in **Table 1**. 7 studies enrolled healthy individuals [23-29], and 3 studies enrolled overweight or obese individuals [30-32]. 7 studies were conducted in USA [23, 24, 26-30], 2 trials were performed in Canada [25, 31], and 1 was performed in Denmark [32]. Participants consisted of both male and females, whose mean ages varied from 18 to 65 years. The intervention periods lasted from 2 to 36 weeks, and all studies were parallel randomized controlled trials that were blinded. The dosage of soy protein ranged from 22 to 70 grams per day, while the dosage of whey protein ranged from 22 to 56 grams per day.

Effect of soy protein and whey protein on lean body mass

7 trials, containing 420 individuals (257 of them in the intervention and the remainder in the control group). were evaluated to investigate the effect of soy and whey protein on lean body mass. Based on a random-effects model, there was a significant increase in lean body mass between the intervention and control groups (weighted mean differences; WMD: 0.69 Kg; 95% CI: 0.13, 1.24; I^2= 68%; $P_{heterogeneity}$< 0.0001). There was no significant effect on lean body mass between intervention and control groups for soy protein (WMD: 0.30 kg; 95% CI: -0.89, 1.50, P= 0.621; I^2= 85%; $P_{heterogeneity}$< 0.0001). Also, there was no significant change in lean body mass between intervention and control groups for soy or whey protein (WMD: 0.87 kg; 95% CI: -0.24, 1.98; P= 0.126, I^2= 0%, $P_{heterogeneity}$= 0.898). There was a significant increase in lean body mass between intervention and control groups for whey protein (WMD: 0.91 kg; 95% CI: 0.15, 1.67, P= 0.019; I^2= 56.9%; $P_{heterogeneity}$= 0.031) (**Figure 2**).

We found that there was no significant publication bias for lean body mass (Eggers test P=0.466). The funnel plot is presented in Supplemental Figure 1.

Effect of soy protein and whey protein on body mass

6 trials, containing 430 individuals (243 of them in the intervention and the remainder in the control group), were evaluated to discern the effect of soy and whey protein on body mass. Based on a random-effects model, there was no significant effect on body mass between intervention and control groups (WMD: -0.63 kg; 95% CI: -1.24, -0.02; I^2= 9.9%; $P_{heterogeneity}$= 0.348). There was no significant effect on body mass between intervention and control groups for soy protein (WMD: -0.58 kg; 95% CI: -1.32, 0.16, P= 0.126; I^2= 0%; $P_{heterogeneity}$= 0.895). Also, there was no significant effect on body mass between intervention and control groups for whey protein(WMD: -0.46 kg; 95% CI: -1.92, 1.00, P=0.537; I^2= 9.9%; $P_{heterogeneity}$= 0.068) (**Figure 3**).

We found that there was no significant publication bias for body mass (Eggers test P=0.279). The funnel plot is presented in **Supplemental Figure 2**.

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Effect of soy protein and whey protein on body fat percentage

2 trials, containing 91 individuals (60 of them in the intervention and the remainder in the control group), were evaluated to investigate the effect of soy and whey protein on body fat. Based on a random-effects model, there was no significant effect on body fat between intervention and control groups (WMD: 0.48 kg; 95% CI: -0.37, 1.33; I^2= 0%; $P_{heterogeneity}$= 0.693). There was no significant effect on body fat between intervention and control groups for soy protein (WMD: 0.81 kg; 95% CI: -0.44, 2.07, P= 0.204; I^2= 0%; $P_{heterogeneity}$= 0.755). Also, there was no significant effect on body fat between intervention and control groups for whey protein (WMD: 0.20 kg; 95% CI: 0.96, 1.36, P= 0.736; I^2= 0%; $P_{heterogeneity}$= 0.354) (**Figure 4**).

We found that there was no significant publication bias for body fat percentage (Egger's test P= 0.241). The funnel plot is presented in **Supplemental Figure 3**

Effect of soy protein and whey protein on fat mass

7 trials, containing 488 individuals (283 of them in the intervention and the remainder in the control group), were evaluated to investigate the effect of soy and whey protein on fat mass. Based on a random-effects model, there was no significant effect on fat mass between intervention and control groups (WMD: -0.03 kg; 95% CI: -0.65, 0.60; I^2= 0%; $P_{heterogeneity}$= 0.994). There was no significant effect on fat mass between intervention and control groups for soy protein (WMD: 0.09 kg; 95% CI: -0.88, 1.07, P= 0.852; I^2= 0%; $P_{heterogeneity}$= 0.871). Also, there was no significant effect on fat mass between intervention and control groups in whey protein (WMD: -0.11 kg; 95% CI: -0.92, 0.70, P= 0.792; I^2= 0%; $P_{heterogeneity}$= 0.987) (**Figure 5**)

We found that there was no significant publication bias for fat mass (Eggers test P=0. 587). The funnel plot is presented as **Supplemental Figure 4**.

Discussion

In the current meta-analysis, whey supplementation, compared to placebo, was associated with a significant increase in lean body mass, with no concurrent change in body mass, fat mass, and body fat percentage. However, soy supplementation, compared to placebo, was not associated with any significant change in lean body mass, body mass, fat mass, and body fat percentage. Subgroup analysis indicated that the duration of intervention may play a role in modifying the effect of whey protein and soy protein in increasing lean body mass. For instance, a significant increase in lean body mass was observed among individuals that received 12 weeks or less whey and/or soy protein. A significant increase in lean body mass was observed among individuals with exercise in the whey protein, but not soy protein, group.

A meta-analysis published in 2018 reported that supplementation may elicit an increase in lean mass, while not influencing fat mass or total body mass [33]. Another study reported a beneficial effect of whey protein on body composition components, including body mass, fat mass, and lean body mass; whilst a greater effect was evident when whey protein supplementation was combined with resistance exercise [34]. In contrast to our findings, a meta-analysis published in 2019 reported a beneficial effect of whey protein supplementation on fat mass. Indeed, there may be several factors that may make a difference in our finding and previous study; for instance, the aforementioned study only included participants who adhered to resistance training, while in our study, participants without resistance training were also included [35]. A recently published meta-analysis indicated that there is no statistically significant overall effect of soy protein on body weight, fat mass, and body fat percentage [36]. Further, discordant with our findings, Mu et al, in a meta-analysis, reported that soy product supplementation reduced body weight and fat mass [37]. However, in Mu et al, the participants were only overweight and obese women, and included various types of soy products, such as soy milk or soy shakes. In contrast, our meta-analysis considered healthy, overweight and obese people. We also considered both genders and included studies with soy protein supplements.

Consumption of whey protein has been indicated to suppress appetite and increase satiety more than other sources of protein, such as casein and albumin [34]. Whey protein provides higher amounts of EAA [35] and has a higher content of leucine, which promotes muscle protein synthesis [38]. Whey protein supplementation after resistance training has been shown to increase whole body net protein balance over 10 to 24 hours of recovery, compared to a rested control day [39]. Indeed, whey protein intake results in an increase in fat metabolism, while decreasing the catabolism of protein [40]. Furthermore, whey protein supplementation has been posited to yield decrements in fat mass through increasing post prandial lipolysis [34].

The mechanisms regarding how soy may decrease adiposity are not well understood. Phytoestrogens, a constituent within soy, may affect body composition directly via binding with estrogen receptors (mostly ERα), by mediating the action of hormones that are involved in the regulation of body composition, such as insulin, leptin, and ghrelin, or by altering the metabolic activity of adipocytes [36]. In addition, soy isoflavones can decrease fat accumulation by restricting fat production and increasing fatty acid beta-oxidation [37].

Strengths and limitations

The main strength of this meta-analysis is that, to our knowledge, this is the first study to have examined the effect of soy protein and whey protein, comparably, on body composition. We performed several subgroup analyses to determine the factors affecting the results. The anthropometric indicators in this study were comprehensive, allowing a detailed insight into supplementation effects. In addition, all studies that were included examined both whey and soy supplementation, yielding a comprehensive understanding of the effect of soy and whey supplementation on body composition. However, despite the novelty of the present study, there are several possible limitations that should be considered. For instance, whey protein and soy protein were used in difference doses in the included studies. Also, study duration was varied among included studies; although, we tried to account for these discrepancies through pre-planned subgroup analyses. The limited sample size of included studies was another limitation, although, clearly, this is beyond the operational control of the study. Finally, most of the included studies were conducted in American countries, with only limited data available from Asian and European countries, thereby highlighting a distinct gap in the literature that should be addressed.

Conclusion

In conclusion, we found that whey protein supplementation was associated with a significant increase in lean body mass, with no concomitant change in body mass, fat mass, and body fat percentage. Additionally, there was a significant increase in lean body mass for whey protein supplementation in individuals performing concurrent exercise and who received 12 weeks or less of whey protein. Finally, soy protein supplementation was not associated with any significant changes in lean body mass, body mass, fat mass, or body fat percentage.

Abbreviations

EAA: Essential amino acid

BCAA: Branched-chain amino acid

LBM: Lean body mass

ER: Estrogen receptor

LBM: Lean body mass

FM: Fat mass

BFP: Body fat percent

mTOR: Mammalian target of the rapamycin

HIV: Human immunodeficiency virus

CI: Confidence interval

WMD: Weighted mean difference

SE: Standard error

SD: Standard deviation

Acknowledgements: This study was supported by the student's Scientific Research Center, Tehran, Iran.

Author contributions: M.P, AM, and K.M. contributed to the study concept and design; M.P and AT designed search strategy and screened papers; S.M. performed statistical analysis; M.P and ED wrote the first draft of manuscript; all authors read and approved the final manuscript.

Funding: Not applicable

References:

1. Lynch, H.M., et al., *No Significant Differences in Muscle Growth and Strength Development When Consuming Soy and Whey Protein Supplements Matched for Leucine Following a 12 Week Resistance Training Program in Men and Women: A Randomized Trial.* International Journal of Environmental Research and Public Health, 2020. **17**(11): p. 3871.
2. Mobley, C.B., et al., *Effects of whey, soy or leucine supplementation with 12 weeks of resistance training on strength, body composition, and skeletal muscle and adipose tissue histological attributes in college-aged males.* Nutrients, 2017. **9**(9): p. 972.
3. Karlsson, H.K., et al., *Branched-chain amino acids increase p70S6k phosphorylation in human skeletal muscle after resistance exercise.* American Journal of Physiology-Endocrinology and Metabolism, 2004. **287**(1): p. E1-E7.
4. MacLean, D., T. Graham, and B. Saltin, *Branched-chain amino acids augment ammonia metabolism while attenuating protein breakdown during exercise.* American Journal of Physiology-Endocrinology And Metabolism, 1994. **267**(6): p. E1010-E1022.
5. Gaudichon, C., et al., *Net postprandial utilization of [15N]-labeled milk protein nitrogen is influenced by diet composition in humans.* The Journal of nutrition, 1999. **129**(4): p. 890-895.
6. Mariotti, F.o., et al., *Nutritional value of [15N]-soy protein isolate assessed from ileal digestibility and postprandial protein utilization in humans.* The Journal of nutrition, 1999. **129**(11): p. 1992-1997.
7. Biolo, G., et al., *Increased rates of muscle protein turnover and amino acid transport after resistance exercise in humans.* American Journal of Physiology-Endocrinology And Metabolism, 1995. **268**(3): p. E514-E520.
8. Blomstrand, E., et al., *Branched-chain amino acids activate key enzymes in protein synthesis after physical exercise.* The Journal of nutrition, 2006. **136**(1): p. 269S-273S.
9. Dickinson, J.M. and B.B. Rasmussen, *Essential amino acid sensing, signaling, and transport in the regulation of human muscle protein metabolism.* Current opinion in clinical nutrition and metabolic care, 2011. **14**(1): p. 83.

10. Dickinson, J.M., et al., *Leucine-enriched amino acid ingestion after resistance exercise prolongs myofibrillar protein synthesis and amino acid transporter expression in older men.* The Journal of nutrition, 2014. **144**(11): p. 1694-1702.

11. Garlick, P.J., *The role of leucine in the regulation of protein metabolism.* The Journal of nutrition, 2005. **135**(6): p. 1553S-1556S.

12. Anthony, J.C., et al., *Signaling pathways involved in translational control of protein synthesis in skeletal muscle by leucine.* The Journal of nutrition, 2001. **131**(3): p. 856S-860S.

13. Anthony, T.G., et al., *Feeding meals containing soy or whey protein after exercise stimulates protein synthesis and translation initiation in the skeletal muscle of male rats.* The Journal of nutrition, 2007. **137**(2): p. 357-362.

14. Clément, K., et al., *Weight loss regulates inflammation-related genes in white adipose tissue of obese subjects.* The FASEB Journal, 2004. **18**(14): p. 1657-1669.

15. Wajchenberg, B.L., *Subcutaneous and visceral adipose tissue: their relation to the metabolic syndrome.* Endocrine reviews, 2000. **21**(6): p. 697-738.

16. Josse, A.R., et al., *Increased consumption of dairy foods and protein during diet-and exercise-induced weight loss promotes fat mass loss and lean mass gain in overweight and obese premenopausal women.* The Journal of nutrition, 2011. **141**(9): p. 1626-1634.

17. Churchward-Venne, T.A., et al., *Supplementation of a suboptimal protein dose with leucine or essential amino acids: effects on myofibrillar protein synthesis at rest and following resistance exercise in men.* The Journal of physiology, 2012. **590**(11): p. 2751-2765.

18. Churchward-Venne, T.A., et al., *Leucine supplementation of a low-protein mixed macronutrient beverage enhances myofibrillar protein synthesis in young men: a double-blind, randomized trial.* The American journal of clinical nutrition, 2014. **99**(2): p. 276-286.

19. Sun, X. and M.B. Zemel, *Leucine modulation of mitochondrial mass and oxygen consumption in skeletal muscle cells and adipocytes.* Nutrition & metabolism, 2009. **6**(1): p. 26.

20. Tahavorgar, A., et al., *Whey protein preloads are more beneficial than soy protein preloads in regulating appetite, calorie intake, anthropometry, and body composition of overweight and obese men.* Nutrition research, 2014. **34**(10): p. 856-861.
21. Volek, J.S., et al., *Whey protein supplementation during resistance training augments lean body mass.* Journal of the American College of Nutrition, 2013. **32**(2): p. 122-135.
22. Brown, E.C., et al., *Soy versus whey protein bars: effects on exercise training impact on lean body mass and antioxidant status.* Nutrition Journal, 2004. **3**(1): p. 22.
23. Brooks Mobley, C., et al., *Effects of whey, soy or leucine supplementation with 12 weeks of resistance training on strength, body composition, and skeletal muscle and adipose tissue histological attributes in college-aged males.* Nutrients, 2017. **9**(9): p. 1-22.
24. Brown, E.C., et al., *Soy versus whey protein bars: Effects on exercise training impact on lean body mass and antioxidant status.* Nutrition Journal, 2004. **3**.
25. Candow, D.G., et al., *Effect of whey and soy protein supplementation combined with resistance training in young adults.* International Journal of Sport Nutrition and Exercise Metabolism, 2006. **16**(3): p. 233-244.
26. DeNysschen, C.A., et al., *Resistance training with soy vs whey protein supplements in hyperlipidemic males.* Journal of the International Society of Sports Nutrition, 2009. **6**.
27. Reidy, P.T., et al., *Protein supplementation has minimal effects on muscle adaptations during resistance exercise training in young men: A double-blind randomized clinical trial.* Journal of Nutrition, 2016. **146**(9): p. 1660-1669.
28. Reidy, P.T., et al., *Protein supplementation does not affect myogenic adaptations to resistance training.* Medicine and Science in Sports and Exercise, 2017. **49**(6): p. 1197-1208.
29. Volek, J.S., et al., *Whey Protein Supplementation During Resistance Training Augments Lean Body Mass.* Journal of the American College of Nutrition, 2013. **32**(2): p. 122-135.
30. Baer, D.J., et al., *Whey protein but not soy protein supplementation alters body weight and composition in free-living overweight and obese adults.* Journal of Nutrition, 2011. **141**(8): p. 1489-1494.
31. Hector, A.J., et al., *Whey protein supplementation preserves postprandial myofibrillar protein synthesis during short-term energy restriction in overweight and obese adults.* Journal of Nutrition, 2015. **145**(2): p. 246-252.

32. Kjølbæk, L., et al., *Protein supplements after weight loss do not improve weight maintenance compared with recommended dietary protein intake despite beneficial effects on appetite sensation and energy expenditure: a randomized, controlled, double-blinded trial.* The American journal of clinical nutrition, 2017. **106**(2): p. 684-697.
33. Bergia, R.E., 3rd, J.L. Hudson, and W.W. Campbell, *Effect of whey protein supplementation on body composition changes in women: a systematic review and meta-analysis.* Nutr Rev, 2018. **76**(7): p. 539-551.
34. Miller, P.E., D.D. Alexander, and V. Perez, *Effects of whey protein and resistance exercise on body composition: a meta-analysis of randomized controlled trials.* J Am Coll Nutr, 2014. **33**(2): p. 163-75.
35. Li, M. and F. Liu, *Effect of whey protein supplementation during resistance training sessions on body mass and muscular strength: a meta-analysis.* Food Funct, 2019. **10**(5): p. 2766-2773.
36. Glisic, M., et al., *Phytoestrogen supplementation and body composition in postmenopausal women: A systematic review and meta-analysis of randomized controlled trials.* Maturitas, 2018. **115**: p. 74-83.
37. Mu, Y., et al., *Soy Products Ameliorate Obesity-Related Anthropometric Indicators in Overweight or Obese Asian and Non-Menopausal Women: A Meta-Analysis of Randomized Controlled Trials.* Nutrients, 2019. **11**(11).
38. Kimball, S.R. and L.S. Jefferson, *New functions for amino acids: effects on gene transcription and translation.* Am J Clin Nutr, 2006. **83**(2): p. 500S-507S.
39. West, D.W.D., et al., *Whey Protein Supplementation Enhances Whole Body Protein Metabolism and Performance Recovery after Resistance Exercise: A Double-Blind Crossover Study.* Nutrients, 2017. **9**(7).
40. Englund, D.A., et al., *Corrigendum: Nutritional Supplementation With Physical Activity Improves Muscle Composition in Mobility-Limited Older Adults, The VIVE2 Study: A Randomized, Double-Blind, Placebo-Controlled Trial.* J Gerontol A Biol Sci Med Sci, 2019. **74**(12): p. 1993.

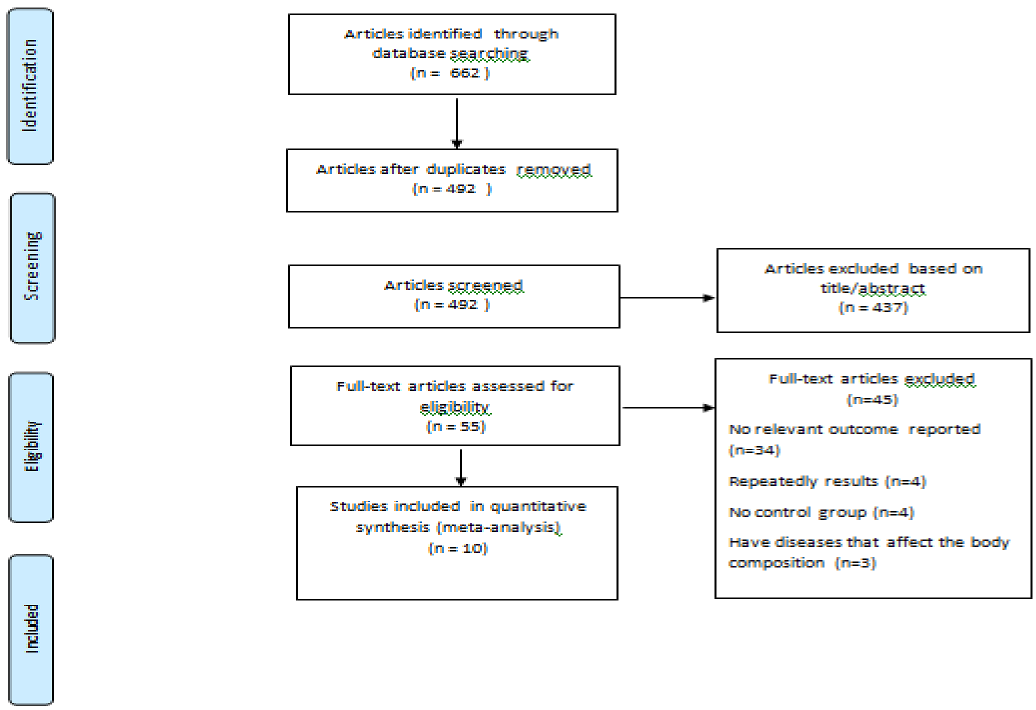

Figure 1. PRISMA flowchart of the study selection process.

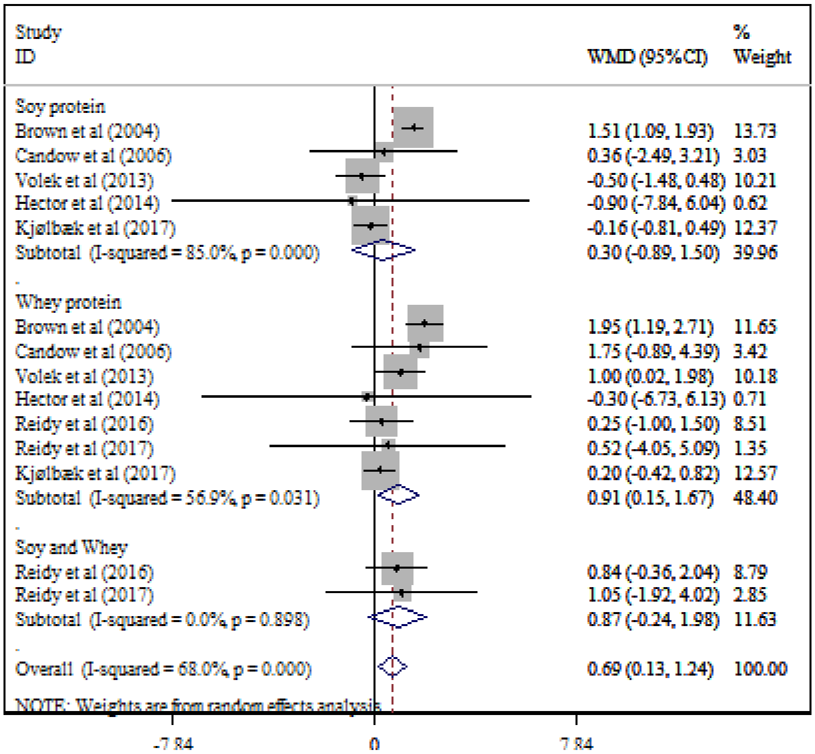

Figure 2. The effect of soy and whey protein on lean body mass

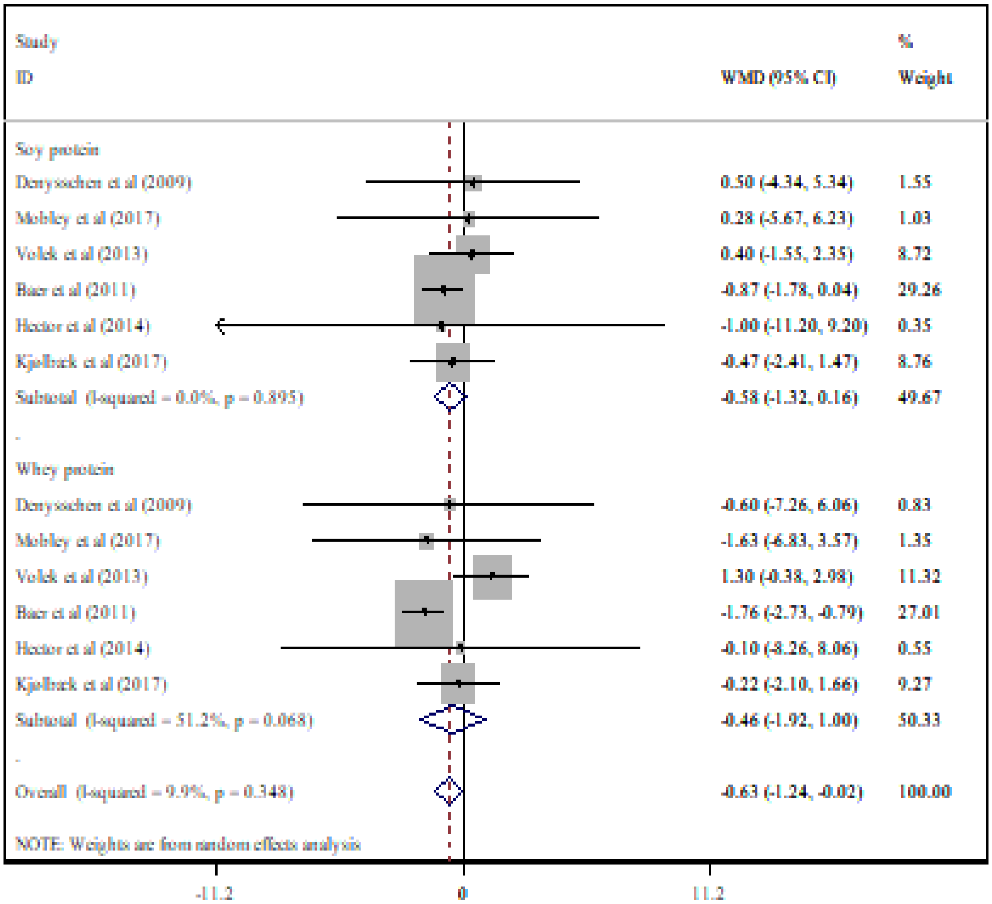

Figure 3. The effect of soy and whey protein on body mass

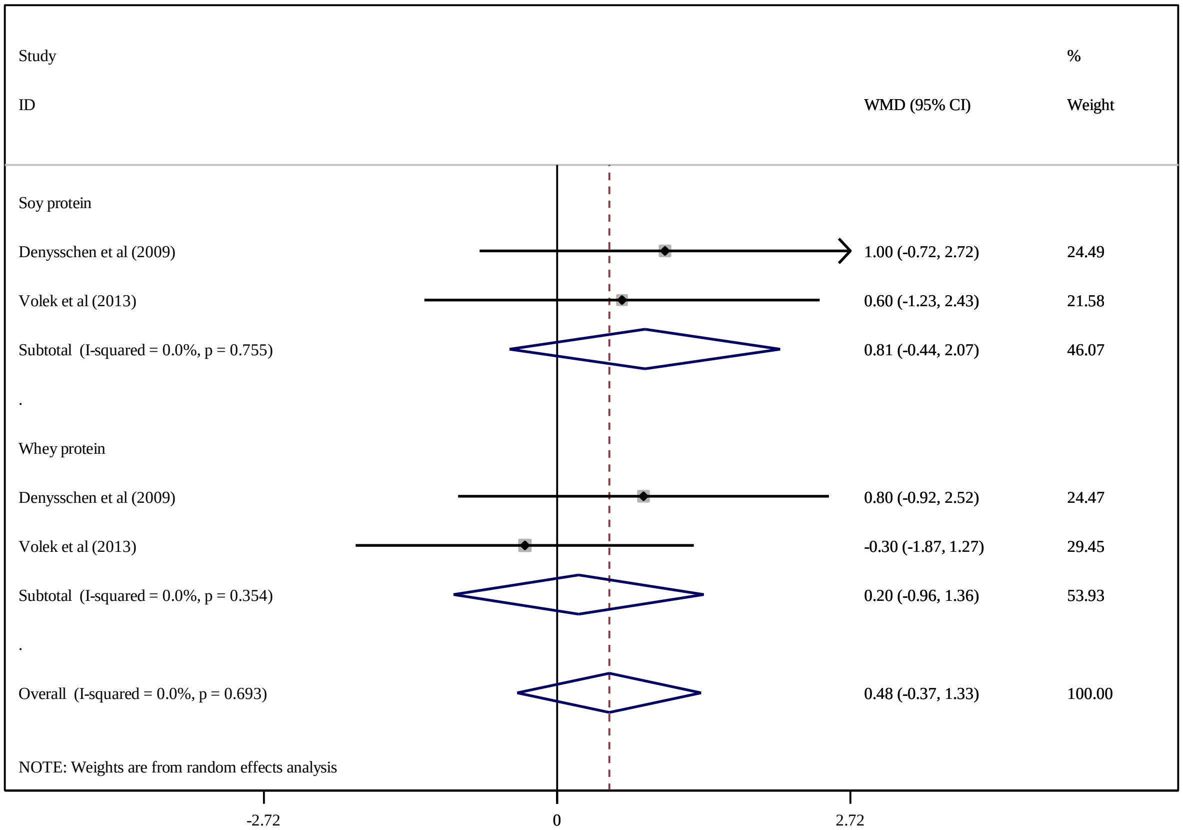

Figure 4. The effect of soy and whey protein on body fat percentage

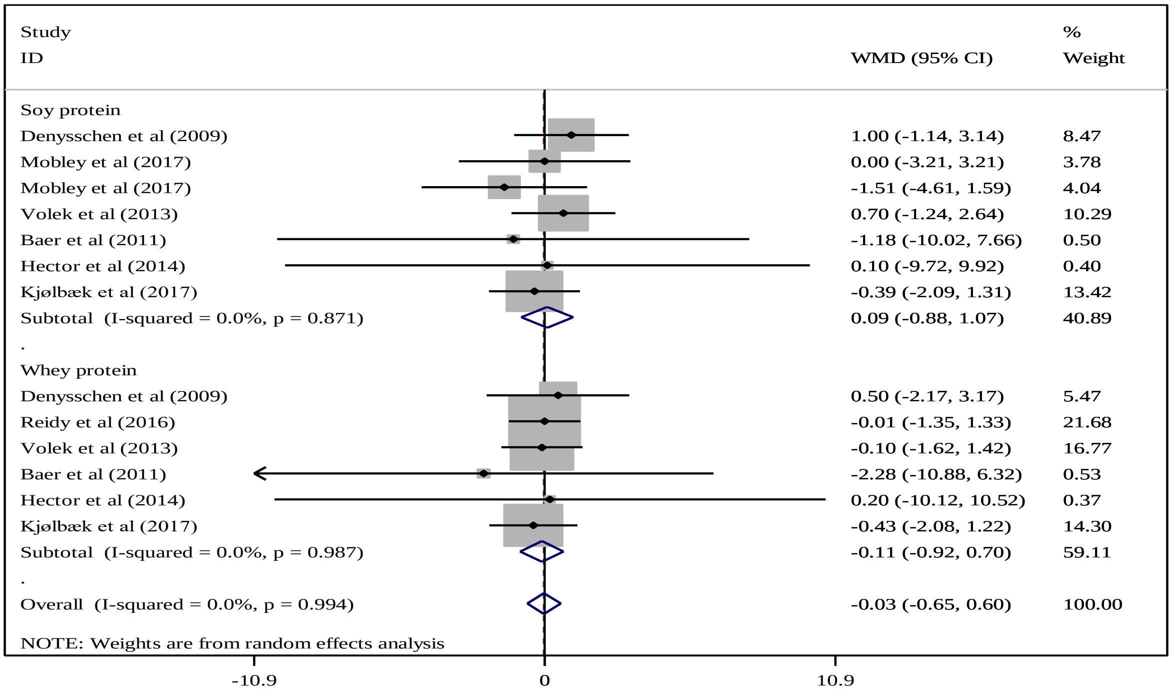

Figure 5. The effect of soy and whey protein on fat mass

Table 1. Characteristics of included studies

Author (year)	**Country**	**Age range (year)**	**Total trial participants**	**Intervention and daily dosage**	**Control and daily dosage**	**Duration (weeks)**	**RCT design**	**Health status**	**Exercise**
Mobley et al. (2017)	USA	19-23	75	Soy protein concentrate, 70 g Whey protein concentrate, 50 g	Maltodextrin 60 g	12	Parallel	Healthy	Yes
Kjølbæk et al. (2017)	Denmark	18-60	151	Soy protein, 45 g Whey protein, 45 g	Maltodextrin48 g	24	Parallel	Overweight and obese	No
Reidy et al. (2017)	USA	18-30	54	Soy protein, 22 g Whey protein	Maltodextrin22 g	12	Parallel	Healthy	Yes

				isolate, 22 g					
Reidy et al. (2016)	USA	18-30	58	Soy protein, 22 g Whey protein isolate, 22 g	Maltodextrin	12	Parallel	Healthy	Yes
Hector et al. (2014)	Canada	35-65	40	Soy protein isolate, 52 g Whey protein isolate, 54 g	Maltodextrin 50 g	2	Parallel	Overweight and obese	No
Volek et al. (2013)	USA	18-35	63	Soy protein, 50 g Whey protein, 56 g	Maltodextrin 50 g	36	Parallel	Healthy	Yes
Baer et al. (2011)	USA		73	Soy protein,	Maltodextrin	23	Parallel	Overweight and	No

				56 g Whey protein, 56 g	52 g			obese	
Denyssche n et al. (2009)	USA	21-50	28	Soy, 30 g Whey, 30 g	Maltodextrin 30 g	12	Parallel	Overweight and obese	Yes
Candow et al. (2006)	Canada	18-35	27	Soy protein, 1.2g/kg Whey protein, 1.2g/kg	Maltodextrin 1.2g/kg	6	Parallel	Healthy	Yes
Brown et al. (2004)	USA	19-25	27	Soy protein, 33 g Whey protein, 33 g	_	9	Parallel	Healthy	Yes

Table 2. Study quality and risk of bias assessment using Cochrane collaboration's tool

Study (year)	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective outcome reporting	Other sources of bias	Overall quality
Mobley et al. (2017)	L	U	L	U	L	L	L	Fair
Kjølbæk et al. (2017)	L	L	L	U	H	L	L	Poor
Reidy et al. (2017)	U	U	L	U	L	L	L	Poor
Reidy et al. (2016)	L	U	L	L	L	L	L	Good
Hector et al. (2014)	U	U	L	U	L	L	L	Poor
Volek et al.(2013)	U	U	L	U	L	L	L	Poor
Baer et al. (2011)	U	U	L	U	L	L	L	Poor
Denysschen et al. (2009)	U	L	L	U	L	L	L	Fair
Candow et al. (2006)	L	U	L	L	L	L	L	Good
Brown et al. (2004)	U	U	L	U	L	L	L	Poor

U; unclear risk of bias, L; low risk of bias, H; high risk of bias.

Table 3. Subgroup analysis for the effect of soy and whey protein on lean body mass

Subgroups		Effect size (n)	WMD (95% CI)	P	I^2 (%)	$P_{heterogeneity}$
Overall		12	0.69 (0.13, 1.24)		68	<0.0001
Exercise						
Soy	With exercise	3	0.53 (-1.12, 2.17)	0.530	85.5	0.001
	Without exercise	2	-0.17 (-0.81, 0.48)	0.614	0	0.835
Whey	With exercise	5	1.24 (0.47, 2.00)	0.001	33.1	0.210
	Without exercise	2	0.20 (-0.42, 0.81)	0.533	0	0.879
Intervention Dose						
Soy	< 50g	2	0.69 (-0.94, 2.33)	0.405	94.4	<0.0001
	>50 g	2	-0.51 (-1.47, 0.46)	0.303	0	0.911
Whey	< 50g	4	0.81 (-0.34, 1.96)	0.166	77.3	0.004
	>50 g	2	0.96 (-0.13, 2.05)	0.084	56.8	0.696
Intervention duration						
Soy	< 12 wk	3	1.48 (1.07, 1.89)	<0.0001	0	0.587
	> 12 wk	2	-0.26 (-0.81, 0.28)	0.338	0	0.570
Whey	< 12 wk	3	1.91 (1.18, 2.63)	<0.0001	0	0.787
	> 12 wk	4	0.37 (-0.12, 0.86)	0.141	0	0.665
Health status						
Soy	Healthy	3	0.53 (-1.12, 2.17)	0.530	85.8	0.001
	Overweight/obese	2	-0.17 (-0.81, 0.48)	0.614	0	0.835
Whey	Healthy	5	1.24 (0.47, 2.00)	0.001	33.1	0.201
	Overweight/obese	2	0.20 (-0.42, 0.81)	0.533	0	0.879
Gender						
Soy	Men	1	1.51 (1.09, 1.93)	<0.0001	-	-
	Men/women	4	-0.25 (-0.78, 0.28)	0.362	0	0.911
Whey	Men	3	1.14 (-0.27, 2.55)	0.114	62.8	0.068
	Men/women	4	0.44 (-0.09, 0.97)	0.102	0	0.465

Table 4. Subgroup analysis for the effect of soy and whey protein on body mass

Subgroups		Effect size (n)	WMD (95% CI)	P	I^2 (%)	$P_{heterogeneity}$
Overall		12	-0.63 (-1.24, -0.02)		9.9	0.348
Exercise						
Soy	With exercise	3	0.40 (-1.33, 2.13)	0.648	0	0.998
	Without exercise	3	-0.80 (-1.62, 0.02)	0.056	0	0.935
Whey	With exercise	3	0.93 (-0.62, 2.49)	0.239	0	0.517
	Without exercise	3	-1.37 (-2.33, -0.41)	0.005	6.4	0.344
Intervention Dose						
Soy	< 50g	2	-0.34 (-2.14, 1.47)	0.716	0	0.715
	>50 g	4	-0.63 (-1.44, 0.19)	0.130	0	0.697
Whey	< 50g	2	-0.25 (-2.06, 1.56)	0.788	0	0.914
	>50 g	4	-0.50 (-2.75, 1.75)	0.663	69	0.022
Intervention duration						
Soy	< 12 wk	1	-1.0 (-11.20, 9.20)	0.848	-	-
	> 12 wk	5	-0.58 (-1.32, 0.17)	0.129	0	0.801
Whey	< 12 wk	1	-0.10 (-8.26, 8.06)	0.981	-	-
	> 12 wk	5	-0.46 (-2.04, 1.11)	0.566	60.8	0.037
Health status						
Soy	Healthy	2	0.39 (-1.46, 2.24)	0.681	0	0.970
	Overweight/obese	3	-0.80 (-1.62, 0.02)	0.056	0	0.935
Whey	Healthy	2	0.91 (-1.04, 2.86)	0.361	9.5	0.293
	Overweight/obese	3	-1.37 (-2.33, -0.41)	0.005	6.4	0.344
Gender						
Soy	Men	2	0.41 (-2.44, 4.17)	0.830	0	0.955
	Men/women	4	-0.62 (-1.38, 0.14)	0.109	0	0.712
Whey	Men	2	-1.24 (-5.34, 2.86)	0.553	0	0.811
	Men/women	4	-0.32 (-2.11, 1.46)	0.721	70.5	0.017

Table 5. Subgroup analysis for the effect of soy and whey protein on fat mass

Subgroups		Effect size (n)	WMD (95% CI)	P	I^2 (%)	$P_{heterogeneity}$
Overall		13	-0.03 (-0.65, 0.60)		0	0.994
Exercise						
Soy	With exercise	4	0.36 (-0.85, 1.57)	0.560	0	0.592
	Without exercise	3	-0.40 (-2.05, 1.24)	0.631	0	0.982
Whey	With exercise	3	0.02 (-0.92, 0.96)	0.968	0	0.928
	Without exercise	3	-0.11 (-0.92, 0.70)	0.577	0	0.987
Intervention Dose						
Soy	< 50g	2	0.15 (-1.19, 1.48)	0.828	0	0.320
	>50 g	5	0.03 (-1.40, 1.46)	0.968	0	0.831
Whey	< 50g	3	-0.09 (-1.06, 0.88)	0.859	0	0.833
	>50 g	3	-0.16 (-1.64, 1.33)	0.834	0	0.885
Intervention duration						
Soy	< 12 wk	1	0.10 (-9.72, 9.92)	0.984	-	-
	> 12 wk	6	0.09 (-0.89, 1.07)	0.853	0	0.779
Whey	< 12 wk	1	0.20 (-10.12, 10.52)	0.970	-	-
	> 12 wk	5	-0.11 (-0.92, 0.70)	0.790	0	0.962
Health status						
Soy	Healthy	3	0.06 (-1.40, 1.53)	0.935	0	0.496
	Overweight/obese	3	-0.40 (-2.05, 1.24)	0.631	0	0.980
Whey	Healthy	2	-0.05 (-1.05, 0.96)	0.924	0	0.931
	Overweight/obese	3	-0.48 (-2.08, 1.12)	0.577	0	0.910
Gender						
Soy	Men	3	0.15 (-1.40, 1.69)	0.854	0	0.425
	Men/women	4	0.06 (-1.20, 1.32)	0.928	0	0.859
Whey	Men	2	0.09 (-1.10, 1.29)	0.879	0	0.738
	Men/women	4	-0.28 (-1.38, 0.82)	0.619	0	0.960