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A Narrative Literature Review: The Effect of Whey Protein Supplementation in Young Adults Engaged in Resistance Training

Bachelor's thesis in Human Movement Science
Supervisor: Karen Emilia Ekman
March 2024

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Abstract

Purpose: Whey protein (WP) has become a central component of modern dietary and exercise routines. Research in this area has progressed significantly. This narrative literature review aims to address whether WP supplementation improves body composition (BC) and strength for young adults engaged in resistance training (RT). **Methods:** The nine studies included in this review were gathered by searching the databases Pubmed and Oria. The main search criteria were RT and WP. Included studies are clinical trials conducted on healthy individuals aged 18-35 years. **Results:** None of the nine studies showed a favorable effect on strength from consuming WP. Four of the nine studies found a favorable effect of WP consumption on BC. **Conclusion:** Research does not indicate that WP will improve strength. Current literature provides contradicting results regarding the effect of WP on BC. Considering the shortcomings in the methodology of the studies included future research is warranted to establish the impact of WP on young adults engaged in RT.

Bakgrunn: Whey protein (WP) har fått en sentral plass i moderne kosthold og treningsrutiner. Forskning innen feltet har økt betydelig de siste årene. Denne narrative litteraturgjennomgangens formål er å adressere om WP forbedrer muskelstyrke og kroppskomposisjon hos unge voksne, som deltar i styrketrening. **Metode**: De ni studiene ble funnet ved bruk av databasene Pubmed og Oria. Hovedkriteriene for at studiene skulle inkluderes var WP og styrketrening. De inkluderte studiene er kliniske studier med deltakere i alderen 18-35 år. **Resultater:** Forskning indikerer at WP ikke forbedrer styrke. Fire studier viste positiv effekt av å konsumere WP når det kommer til kroppskomposisjon. **Konklusjon**: Forskning indikerer at WP ikke forbedrer styrke. Nåværende litteratur viser motstridende funn når det kommer til effekten av WP på kroppskomposisjon. Med tanke på manglene i metodene, er det behov for videre forskning for å fastslå om WP har effekt på unge voksne som driver med styrketrening.

Keywords: strength training, protein powder, protein reservoir, emerging adults, weight training, dietary regime, nourishment, students.

Introduction

The interest in Whey protein (WP) has grown within the health and fitness society, particularly among young adults. WP has become a central component of modern dietary and exercise routines, and research in this area has progressed significantly. In 2022, a Canadian study on dietary supplement use among young adults found that 63.1% include WP in their daily diets. Notably, 82.5% of young men reported regular use (Ganson *et al.* 2022).

Despite widespread consumption of WP, its impact on health remains uncertain. Among others, Cava et al. suggest that excess WP intake may pose a risk to liver, kidney, and skin health (Cava *et al.*, 2024). WP supplementation alters the gut microbiome, reducing beneficial bacteria (Moreno-Pérez *et al.*, 2018). On the other hand, later research revealed improvement in intestinal bacteria concentration from consuming WP (Cava *et al.*, 2024). Contradicting findings on WP's side effects on health-related factors raise questions about the supplement. Therefore, further research is warranted to assess its long-term impact on health.

WP is considered a high-quality protein source as it contains a higher concentration of indispensable amino acids (Naclerio and Seijo, 2019). WP is a mixture of casein and globulins contained in whey from cheese production. Due to its rapid absorption and high nutritional value, WP is the most used protein supplement (González-Weller *et al.*, 2023). Protein supplementation is one of the common nutritional strategies to increase muscle protein synthesis post-resistance training (RT), for greater gains in muscle mass and strength (Jacinto *et al.*, 2022) (Weisgarber *et al.*, 2012).

Protein consists of essential amino acids that need to be consumed through diet. A constant breakdown and build-up cycle throughout the day allows damaged protein to be removed and replaced by new protein in response to exercise (Jeffreys and Moody, 2016). Daily protein intake recommendations to grow and develop skeletal muscle is between 1.2-2.2 grams per kilogram of body weight. It has been shown that essential amino acids are primary regulators of muscle protein synthesis (Lee E. Brown, 2007).

Protein synthesis and breakdown are stimulated by RT. The balance between the synthesis and breakdown of protein, known as the net protein balance, determines the anabolic response to protein ingestion. Consuming amino acids before and after exercise accelerates protein synthesis by stimulating the transportation of amino acids to muscles (Lee E. Brown, 2007). RT is a proven method to develop muscular adaptations; strength, hypertrophy, and muscular endurance (Schoenfeld *et al.*, 2021). Studies on the consumption of WP together with RT to develop these muscular adaptations need to be explored further.

Considering the uncertainty surrounding the side effects of WP consumption, this thesis research question is:

> *"Does current literature demonstrate whey protein as beneficial or unnecessary in combination with resistance training for young adults?" Is there justification for widespread WP use?*

Due to the prevalence and lack of exploration of the long-term effects of WP consumption, a necessity to conduct a literature review on this matter is raised. The contribution of this thesis to future research is guidance in a more targeted direction. This bachelor's thesis investigates literature on WP combined with RT, on muscle strength and BC for young adults.

Method

The literature search for this thesis was conducted using the database Oria and PubMed on January 18, 2024. The search terms used to locate the literature utilized were ((Whey) OR (Protein powder)) AND ((strength) OR (training) OR (Resistance training)) AND ((Young adults) OR (Students)). Filters of clinical trials and randomized controlled trials were applied to PubMed to limit the results. There were 54 results on Oria and 140 on PubMed. Nine studies were considered relevant after going through the inclusion and exclusion criteria.

Table 1: *Inclusion and exclusion criteria in the assortment of original articles*

Inclusion Criteria	Exclusion Criteria
Studies conducted on young adults. Aged 18-35 years.	Studies conducted on children, older adults, and animals.
Studies conducted on healthy individuals.	Studies conducted on individuals with chronic illnesses.
Studies written in English.	Studies written in other languages than English.
Studies assessing the effect of WP on BC and/ or muscle strength.	Studies evaluating the effect of protein bars, plant-based protein, dietary protein, creatine, vitamins, and minerals.
Studies conducted on RT.	Studies conducted on other forms of exercise than RT.
Studies lasting more than 48 hours.	Studies lasting less than 48 hours.

Results

Table 2: *Descriptive Overview of Original Articles*

Article	Research	n	Demographics	Physical fitness level	Duration (Week)	Rep range	Comparison	Testing methods		Dietary record	Findings
								Body composition	Strenght		
(Erskine et al, 2012)	RCT	33	Males aged 23 ±3	No RT on upper body 12 months before the study.	12	8-10	WP (2x20g P) Vs. placebo	**MRI** to determinat maximum anatomical CSA and **Skinfold**, body mass, height.	**1RM** unilateral bicep curls with dumbbells, MVF isometric maximal voluntary force testing,	3-day dietary tracking, during weeks 3 and 12 of the study.	No significant effect from WP.
(Farup et al., 2014)	RCT	22	Males aged 23.9 ± 0.8 years	No RT or HIIT on lower body 6 monts before the study.	12	6-15	WP (19,5g P) Vs. isoenergetic carbohydrate	**MRI** scans of both thighs and patellar tendons.	**Isokinetic dynamometer** and **EMG** mesuing muscle activity in m. vastus lateralis and m. vastus medialis.	No dietary records collected.	Greater impact on MCSA observed when consuming WP Vs. consuming a placebo.
(Hambre et al., 2012)	RCT	24	Males between the age of 19 and 32 years	No RT 6 months before the study.	12	8-10	WP (33g P) Vs. Fast food	**DXA.**	Hamstrings and quadriceps strenght tested by using a **Biodex machine**.	A 7-day dietary diary compleated at both the start and the end of the study.	No significant difference in lean body mass between intake of extra high kcal meal and WP.
(Herda et al, 2013)	RCT	106	Between the age of 20 and 24	Combination of fit and unfit.	8	6	Two types of WP (27g P) Vs. placebo Vs. control group	Residual volume was determined using the **oxygen dilution method**, and body volume from **hydrostatic weighing**. MCSA was messured by two-dimensional images of the right thigh using a **peripheral quantitative computed tomography** (pQCT) scanner.	**1RM** bench press and leg press.	A 3-day dietary diary compleated both before and after the study.	No difference in muscle strength or body composition.
(Hwang et al., 2017)	RCT	20	Males between the ages of 18 and 30	Minimum 1 year experience with RT before the study.	10	10	WP (25g P) Vs. maltodextrin (Placebo	**DXA** measured body weight, total body water, fat-free mass and CSA of rectus femoris by **ultrasonography.**	**1RM** to test strenght, RM on 75% - Muscle endurance.	A 4-day dietary diary 4 times during the study.	No significant difference in lean body mass. No significant difference in the rectus femoris CSA. No difference in leg strenght.
(Jacinto et al, 2022)	RCT	22	Aged 25.2 ± 5.8	Not participating in structured RT 6 months prior.	10	8-12	High-quality WP (35g P) Vs. lower protein quality CP supplement	Axial images of the vastus lateralis and biceps brachii muscles using a **B-mode Doppler ultrasound** and a 10 MHz linear array probe.	**Isokinetic dynamometer (Biodex, Inc., Shirley, NY).** and countermovement jump.	3-day tracking at weeks 1, 3, 7 and 10.	WP is superior to CP for muscle size, not for strength and power
(Sharp et al, 2018)	RCT	41	Aged between 18 and 30	2 years experience with RT.	8	8-15	WP (46g P) Vs. chicken protein Vs. beef protein Vs. Maltodextrin (Placebo)	**DXA** to measure lean body mass and fat mass.	**1RM** bench press and deadlift.	Individual-based diet and tracking daily intake.	Protein supplement supported muscle protein accretion, regarding the source.
(Vatani & Kani, 2012)	RCT	30	Healthy overweight males age 23.4±3.6 (BMI 25-30)	No RT 6 months before the study.	6	6-12	WP (30g P) Vs. placebo Vs. a control group who did not participate in RT	Waist-to-hip ratio was measured with a **tape measure**, BMI was calculated by **dividing weight by height squared**, and skinfold thickness was assessed using **Lange skinfold calipers**. Body fat percentage was estimated using the **4-site formula** from ACSM's Resource Manual for Guidelines for Testing and Prescription.	**1RM** test Squat, bench press, lat pull-down, standing EZ-curls, cable triceps extensions, and back press.	24-hour tracking, both before and after the study.	RT improves body composition and the antioxidant system.
(Weisgarber et al. 2012)	RCT	17	Aged 24.58 ± 1.8 years	No RT 6 months before the study.	8	6-10	WP (0.3g/kg) Vs. placebo	**DXA** to assessed Whole-body lean-tissue mass, fat mass, and bone mineral content were and a **B-module ultrasound** to asess Elbow- and knee-flexor and -extensor and ankledorsiflexor and plantar-flexor muscle thickness.	**1RM** chest press, lower body strength was not tested due to broken equipment.	Tracking diet the first and last week of the study, for 3 days.	No results from consuming WP.

Table descriptives*: RCT= randomized controlled trials, n= subjects in intervention, Rep range= repetition in RT interventions, duration= training duration in weeks, physical fitness level= level of experience with RT, demographics= population characteristics, comparison= supplements compared in the study, dietary records= amount of dietary tracking and how long, testing methods= tests used to assess BC and strength, MCSA= muscle cross-sectional area, HIIT= high intensity interval training, P= protein, WP= whey protein, RT= resistance training, CP= collagen peptides, BMI= body mass index, MRI= Magnetic Resonance Imaging, DXA= dual-energy X-ray absorptiometry, RM= repetitions maximum, EMG= Electromyography.*

Please look at the appendix for a more refined version of Table 2.

Erkins *et al.*, (2012) conducted a study to investigate if WP had an effect on muscle size, strength, and architecture in the elbow flexor muscle combined with RT. The participants were assigned either to a protein or a PLA supplement group. Exercises performed were unilateral biceps curls and modified preacher press with increasing resistance when participants could conduct more than 10 reps during the final set. In weeks 1-3, there were 2 sets for each exercise, increasing to 3 sets for unilateral bicep curls in weeks 3-4. Weeks 5-12 had 3 sets of each exercise. There was no significant difference in muscle size between the protein supplement and PLA group ($p \leq 0.001$). No difference in muscle strength was observed between the WP and PLA groups ($p \leq 0.001$). The protein supplement group had increased protein intake on training days, but there was no difference in protein intake between the two groups averaged across the week.

Farup *et al.* (2014) aimed to examine the impact of maximal dynamic RT combined with either WP or a PLA on muscle and tendon hypertrophy. Subjects were assigned into two groups: one consuming a high-leucine WP hydrolysate + carbohydrate supplement (WHD), or one PLA group consuming carbohydrates (PLA). Participants underwent sessions featuring two contraction modes: concentric contractions on one leg and eccentric contractions on the other. Results indicated a significant increase in quadriceps Cross-sectional area (CSA) in both groups, notably greater in WHD compared to PLA ($p < 0.01$). Proximal patellar tendon CSA increased significantly more in WHD than in PLA ($P < 0.05$). Both maximal voluntary contraction and rate of force development increased ($P < 0.001$ and $P < 0.05$), without any notable group difference. The study concluded that training-induced hypertrophy of both tendons and muscles was enhanced with the inclusion of a high-leucine WP hydrolysate supplement.

Hambre *et al.*, (2012) aimed to investigate the effect of RT with increased protein intake or increased kilocalorie (kcal) intake on lean body mass, strength, cardiovascular risk factors and resting metabolic rate (RMR). The participants were asked to execute 1 hour of RT 3 times a week containing 3-5 sets each exercise. The subjects were divided into groups; one taking a protein supplement and one eating a fast-food meal containing approximately 1350 kcal a day, in addition to a regular diet. Both groups gained body weight with no significant difference between groups ($p=0.4$). Increases in lean body mass and muscle strength were similar, but the fast-food group increased body fat significantly ($p=0.028$). At the end of the study, there were no significant differences between groups in body fat (p=0,4) or strength (p=0.23 quadriceps, p=0.9 hamstrings). No difference between groups in RMR (p=0.27) was observed at the end of the study. Changes in RMR per kg lean body mass were independent of caloric or protein intake (all p=0.5). Homeostatic model assessment, the marker of insulin resistance increased and the index of insulin sensitivity, decreased in the fast-food group post-study. Levels of fasting insulin also increased more in the group consuming fast-food (all $p < 0.05$) post-study.

Herda *et al.,* (2013) investigated the effect of two types of protein supplementation on thigh muscle CSA, blood markers, muscular strength, endurance, and BC after low-or moderate-volume RT. Participants were divided into 5 groups; (1) bioenhanced WP (BWP) with low-volume training (BWPLV), (2) BWP with moderate-volume training (BWPMV), (3) standard WP with moderate-volume training (SWPMV), (4) PLA with moderate-volume training (PLA), and (5) control with moderate-volume training (CON). RT was performed 3 times per week. For the low-volume group, the sets were: 1 in Week 1, 2 in week 2, and 3 in week 3-8. For all other groups sets were: 3 in week 1, 4 in week 2, and 5 in week 3-8. There were no significant differences between the group's adjusted mean values for muscular strength- and BC variables (p>0.05) post-study. Groups 1, 2, and 3 consumed significantly more protein compared to groups 4 and 5 (p=≤0.000) during the study.

Hwang *et al.,* (2017) aimed to assess if a 2-week detraining (DT) period would impact gains in muscle mass and lower body strength after 4 weeks of RT. Additionally, they examined the effects of DT on muscle mass and strength following 4 weeks of retraining (ReT). Lastly, assess the influence of WP or carbohydrate supplementation on muscle performance and body composition. The study compared two groups consuming either WP or placebo. Participants completed 2 upper-body and 2 lower-body sessions per week, doing 3 sets of each exercise, followed by a 14-day DT period with no formal training before the ReT period. There were no significant differences between groups in total lean- and fat mass changes (p>0.05) post-study. No significant difference between groups in the rectus femoris CSA (p>0.05) post-study was observed. Both groups had significant increases from baseline in leg press strength post-study (p≤0.05), with no significant difference between groups.

Jacinto ***et al.*** **(2022)** compared the effect of WP supplementation versus leucine-matched collagen peptides (CP) on muscle thickness after following an RT program. The subjects were divided into one WP group and one CP group. The RT program had 3 sessions per week containing 3 sets for each exercise. There was no difference in macronutrient intake between the two groups ($p>0.05$) during the study. Muscle thickness increased more in the WP group than in the CP group ($p<0.05$) post-study. Both groups had similar increases in mean power output and peak torque ($p\leq0.001$) during the study, but no significant differences between groups in peak power output for both the lower and upper body ($p\leq0,05$).

To investigate the effect of dairy-protein versus meat-based protein sources on body composition, muscle strength and power, **Sharp** ***et al.,*** **(2018)** divided participants into 4 groups consuming either: WP, isolated beef protein, hydrolysed chicken protein, or PLA (control). All participants followed an identical training protocol containing two hypertrophy and one strength-training session per week. Participants received the given supplement each day in addition to the recommended diet for the complete study period. This study found no significant difference in muscle strength between control and protein groups ($p\leq0.01$) post-study. There was a significant difference in body BC between the control and protein groups post-study. All protein groups increased lean body mass and decreased fat mass ($p\leq0,0001$) post-study. There were no significant differences between protein groups in body composition.

Vatani D. and Golzar F., (2012) aimed to investigate the effect of WP with RT on antioxidant status and cardiovascular risk factors including body composition. Subjects were divided into 3 groups: WP supplement, PLA supplement, or control group (CON) (c) who did not participate in RT nor take supplementation. Participants performed 3 RT sessions per week. Both WP and PLA reduced body fat percentage and fat mass compared to the C group ($p\leq0.05$) during the study. Differences in vitamin C and cholesterol were not significant between the three groups ($p\leq0.05$) post-study. There were no significant differences between WP and PLA for the different measurements post-study.

Weisgarber ***et al.,*** **(2012)** aimed to assess the effects of WP on BC and strength. Participants were randomly assigned to groups: one consuming WP and one consuming PLA. Overall, the PLA group was more active than the WP group during the study. The group consuming WP had a higher intake of protein and a higher intake of Kcal. Participants underwent RT 4 days a week, completing 3 sets. The increase in muscle size was significant for both groups ($P < 0.05$), with no difference between groups post-study. There was a noteworthy rise in the volume of training performed for all exercises over time for all participants ($P < 0.05$), with a greater increase in the WP group compared to the PLA group for lower extremities exercises. There were no significant differences in chest-press strength between groups, but an increase for all the participants ($p \leq 0.05$) from baseline to post-study. Body mass, lean tissue mass and bone mineral content showed no changes throughout the study, nor any group differences.

Discussion

The results from this thesis show contradicting findings on the effect of WP in combination with RT for BC variables, and no effect regarding strength. Four studies showed favorable BC changes from consuming WP. One study (Vatani, D. & Golzar, F., 2012) showed improved BC from RT regardless of supplementation. In the following, factors possibly affecting the results are presented.

Strength

Based on the results of this review, consuming WP does not increase muscle strength. Seven of the studies looked into strength as a variable to investigate the effects of WP supplementation. All seven studies found an increase in strength after regular participation in RT, but no greater increase in groups ingesting WP compared to non or other dietary additions.

A reason for WP supplementation showing no greater impact than RT alone may be that six studies were conducted on untrained individuals. The results may originate from the progression in strength during the early stages of RT possibly due to higher amounts of motor neuron activation and adaptations at the cortical or spinal level (Del Vecchio *et al.*, 2019). By conducting the same study on individuals with experience in RT, the results could be different as the initial neural adaptations to RT would not be a contributing factor to strength development. However, the WP group in Weisgarber *et al.* had a greater increase in the volume of training for lower extremities exercises than PLA which indicates greater improvement in strength. Due to broken equipment, strength in the lower extremities was not tested.

Two studies, Sharp *et al*., (2018) and Hwang *et al.,* (2017), were conducted on trained individuals who also did not find any greater increase in strength from consuming WP compared to CON.

Body Composition

The effect of WP alongside RT on BC has mixed results based on the literature. Farup *et al`s.*, (2014) findings indicate a more favorable BC from taking WP based on increased muscle mass with the same fat and bone mass. These findings may highlight a necessity for further investigation of the impact of WP to enhance body composition. Jacinto *et al.*, (2022) found larger muscle thickness from consuming high-quality protein supplementation compared to low-quality protein indicating greater muscle growth from consuming WP in addition to RT. Results from Sharp *et al.,* (2018) indicate an improvement in BC from consuming protein supplementation regarding high-quality sources for trained individuals as all protein groups had improved BC compared to the CON. This indicates greater muscle hypertrophy from consuming protein supplements when there is a familiarity with RT. Looking at the results from Jacinto *et al.* (2022) and Sharp *et al.* (2018), the quality of protein is important when aiming to improve BC through RT with protein supplements.

One of the studies (Hambre *et al.*, 2012), found a similar gain in lean body mass between groups consuming extra protein or extra kcal, but a larger increase in fat mass for the extra kcal group. Overfeeding by consuming more kcal than burned per day is one of the most used strategies to build muscle (Kreider, 1999). Based on Hambre et al's results, WP compared to extra kcal consumption, leads to a similar increase in muscle mass without an increase in fat mass improving BC. The fast-food group had less body fat than the protein group before the study which explains the lack of significant difference between groups in body fat post-study. Looking at the fat mass gain in kg, the extra kcal group almost doubled the increase in fat mass compared to the WP group.

On the contrary, four studies found no greater improvement in BC variables from taking WP in addition to RT. Results from Weisgarber *et al.,* (2012) and Erskin *et al.* (2012) found no greater improvement in muscle size from consuming WP compared to PLA. Hwang *et al.,* (2017) found no difference from taking a carbohydrate supplement or WP in lean body mass, fat mass, and muscle CSA indicating that WP will not lead to greater improvements in BC with RT. However, the discussion revealed that the protein group had a greater increase in lean body mass (1.58 kg) compared to the PLA group (0.34kg) throughout the study. Herda *et al.,* (2013) found no difference in BC values between the groups indicating that WP supplementation is unnecessary for improving BC when practicing RT regarding training volume. The authors concluded that the supplementation of protein is necessary when low-volume RT is conducted to achieve the same results as moderate-volume RT but to make this conclusion, a sixth group who conducted low-volume RT with PLA supplement is beneficial. These results contradict claims that additional protein with RT leads to an anabolic response of muscle, considering muscle size would have increased significantly in WP groups compared to PLA groups if this were to be true.

The common factor for all studies that showed improvement in BC from baseline, is participation in RT. Based on the contradicting findings regarding the effect of WP on BC, RT is the main cause of improvement in BC, regarding WP supplementation. The findings in this thesis do not indicate whether the widespread use of whey protein is justified for improving BC.

Methodological limitations and benefits

All the studies utilized small sample sizes ranging from 17 to 41 individuals, except Herda *et al.,* (2013) who included 106 participants, providing a more representative sample. However, the small sample sizes in most studies make generalization challenging and weaken reliability due to increased randomness and limited statistical power. Conversely, smaller samples allow for meticulous dietary patterns and training protocol tracking. Controlling variables could increase internal validity and reliability but reduce opportunities for subgroup analysis.

The reliability of the studies may be affected by the short duration, ranging from 6 to 12 weeks. The short duration could limit the observed changes in BC and strength. Research by Mortani and deVries (1979) indicates that neural factors, such as improved muscle cell activation and coordination of muscle contractions, play a dominant role in the first three to five weeks of strength training. Indicating that early strength gains are primarily due to enhancements in the nervous system and neuromuscular control before hypertrophy becomes the primary factor (Mortani and deVries., 1979). Therefore, neural factors may explain why four out of the studies, three of which were conducted on untrained individuals, did not show significant effects on BC. Despite attempting to prevent neural factors from overshadowing, by implementing three weeks of RT before the study, Erskine et al. did not find significant results. The absence of results could be explained by three weeks being insufficient for neural changes to stabilize.

The length of the studies was justified by citing existing research, for example, the study conducted by Candow *et al.*, (2011) which has shown that ≤8 weeks of structured resistance training is sufficient to increase muscle mass and strength among untrained adults. Indicating that the duration of eight of the nine studies utilized in this thesis is sufficient to observe results.

The testing methods used to assess BC and strength could affect the literature's results. DXA and MRI are set to golden standards as BC measurements. Despite being the golden standard, DXA and MRI estimate 73% of lean body mass as water. Due to individual differences, water percentage may fluctuate from day to day and among individuals. Skinfold measurements depend on both the person taking the measurements and the distribution of body fat. Considering one study using the skinfold method was conducted on overweight participants, the accuracy of the measurements may be compromised, due to challenges associated with correctly measuring individuals with high fat mass and could weaken the validity of the test. However, the study categorized overweight by BMI<30, which does not reflect fat and muscle mass ratio, possibly categorizing individuals with high muscle mass as overweight.

Resistance training protocols

All training programs used in the studies, except one, are structured with mostly sessions to grow muscle using the 8-12 rep range said to optimize hypertrophy (Schoenfeld *et al.*, 2021). Seven of the studies aimed to investigate strength but used the rep range 8-12. Heavy load and lower rep range (1-5) are shown to be more beneficial for strength development (Schoenfeld *et al.*, 2021). Strength gains from heavy load are mostly due to neuromuscular adaptations which lead to increased force production and psychological factors such as familiarity with exerting maximal effort (Schoenfeld *et al.*, 2021). Considering this, the results regarding strength could have been different for the 7 studies if the RT were structured otherwise. However, hypertrophy contributes to strength gains (Erskine, Fletcher and Folland, 2014), which could explain strength development for all participants regarding supplementation or not in all studies.

One of the studies (Herda *et al.*, 2013) had two WP groups conducting low- or moderate-volume RT while the PLA conducted moderate-volume and used a lower rep range (6). The lower rep range leads to heavier loading and familiarity with heavy lifting for the participants. This could contribute to more strength gains in the results compared to studies where participants conducted a higher amount of reps. Sharp *et al.*, (2018) both included strength and hypertrophy sessions leading to the possibility of gaining muscle mass together with specific strength training contributing to neural adaptations and psychological familiarity.

The level of control over the RT in the nine studies varies. Four studies had a trained instructor present during sessions. One study, by Weisgarber *et al.,* (2012) had a rundown of the exercises with an instructor, but the RT was conducted alone. In one study, Herda *et al.*, (2013) gave a written instruction of the exercises and completed the sessions alone. For individuals unfamiliar with RT, written instructions can lead to variation in the exercise performance within the group. Hambre *et al.*, (2012) only gave instructions to spend 1 hour in the gym together with the reps and sets ratio. Leaving the structuring of the RT programming to the participants, without experience or educational knowledge on the topic, may lead to uncertainties considering the quality of the training. The author attributes this to the general population lacking access to professionals. However, the variability in the subject's resistance training weakens the reliability when studying the effect of supplementation alongside training.

Dietary intake

Nutritional intake influences the response to RT (Volek J.S., 2003), therefore the control of dietary intake is interesting to monitor when conducting studies on WP and RT. Knowledge surrounding the participant's dietary intake varies across the nine studies.

Five of the studies had no difference in macronutrient intake between groups. Three of these five studies showed no difference when consuming WP in strength or body composition. The lack of difference between groups could be explained by similar macronutrient intake. However, if WP would give favorable results, it is necessary to match macronutrient intake during the studies. Two studies showed favorable BC for groups consuming high-quality protein supplementation. Based on these contradicting findings, more research surrounding the use of WP to build muscle and manage BC is necessary.

Three studies had the WP group consuming a higher amount of protein compared to opponent groups. Of these three studies, only one had favorable results regarding WP (Hambre et al., 2012). The protein group in Hambre *et al.*, (2012) had significantly more protein consumption (P=0.005) than the fast-food group. However, the fast-food group consumed on average 650 kcal more each day resulting in a similar gain in lean body mass for both groups but, as mentioned earlier, a difference in fat mass.

Two of the studies had subjects in a hypocaloric state. Neither of these showed any difference between groups for BC or strength. Hwang *et al*., (2017) found no increase in muscle size, which is expected from being in a calorie deficit, however, Weisgarber *et al.*, (2012) had an increase in CSA for both groups even though all subjects consumed less kcal at the end, compared to before the study. Considering the participants were in a calorie deficit, there were expectations to see a loss in fat mass and/ or body mass, but this did not occur. The gain in CSA is unexpected considering muscle building requires a positive energy balance either from kcal or protein (Lambert, Frank and Evans, 2004). Considering subjects reporting their own dietary intake, the reporting could be unreliable and invalid. Participants could for example eat more restrictive on the days they tracked diet or underreport.

Farup *et al.,* (2014) did not track the participant's diet at any point. The results found favorable CSA for the group consuming WP. Considering the lack of dietary recording, the results are impossible to determine is due to increased protein consumption from the diet, higher kcal consumption, or the WP supplementation itself. Therefore, the results favouring WP for muscle hypertrophy are invalid.

The effect of WP on Individuals experienced vs. inexperienced in RT

Herda *et al*., (2013) suggest that their sample, consisting of primarily individuals inexperienced with structured RT, could lead to the significant effects of RT overshadowing any additional benefits of WP. This suggestion may apply to several of the studies.

The two studies that looked into experienced participants had contradicting findings on BC. Sharp *et al.,* (2018) as mentioned earlier, showed a favorable change in BC from consuming high-quality protein supplements. Therefore, if future research determines no long-term health consequences, WP could be used as equivalent to beef and chicken protein for experienced individuals. Hwang *et al.*, (2017) as mentioned earlier found no difference between the consumption of WP or not for BC and strength, but dietary intake could cause the lack of results in this study. Given that participants were in a hypocaloric state, the results cannot be transferred to conclude the efficacy of WP. Even though the statistical analysis does not show a significant difference, the discussion presents mean values showing a greater gain in lean body mass for the protein group compared to the placebo group. To interpret these findings, supplementation with WP could contribute to growing lean body mass during a hypocaloric state for experienced individuals. However, research suggests the requirement of a positive energy balance from either extra kcal or protein to grow muscle tissue (Lambert *et al.,* 2004).

Three of the six studies conducted on inexperienced individuals showed favorable effects from taking WP compared to the opponent group regarding BC. No difference was observed in strength which could be explained by neural adaptation as mentioned earlier. Farup *et al.*, (2014) lacked dietary records which makes the results less reliable. Hambre *et al.*, (2012) only gave WP a favorable effect compared to fast food. WP could be a healthier alternative considering reduced insulin sensitivity and higher ApoB levels in addition to more fat tissue in the fast-food groups, which could negatively affect long-term cardiovascular health. The results could be different if the caloric surplus were from a healthy diet. Jacinto *et al.*, (2022) compared WP to lower-quality CP finding a favorable effect in CSA from high-quality protein consumption indicating an effect in muscle building. However, all of these studies have limitations making the results non-transferable to conclude the effects of WP on individuals inexperienced with RT. Given the limitations, it is not possible to conclude that WP has positive effects on inexperienced individuals regarding BC or strength.

Future research

Research concerning nutrition often focuses on population averages, but considering the high between-person variability in response to diet, a personalized approach could be more beneficial (Berry *et al.*, 2020). Considering the different responses to diet among individuals, this could also apply to WP. Small *n* may result in effects pointing in different directions not being detected. For more comprehensive insights, future research could explore the variance to assess the spread, which can determine whether segmenting into subgroups is advisable. This approach may uncover differences not apparent within a small sample size.

Based on weaknesses identified in the methodology, it could be adequate for future research to standardize both diet and training protocols. Closer follow-up and WP being the only independent variable could also be profitable. However, if WP is highly potent, it may not be necessary to specify the training protocol and diet, indicating that WP is unnecessary for the general population. Nevertheless, further research is required to evaluate whether WP could play a significant role in the progression of athletes or highly advanced individuals. Due to the unclear benefit-risk balance, it could be interesting for future researchers to investigate the potential long-term effects to make recommendations regarding the use or advice against WP.

Conclusion

The current literature does not provide enough evidence to state any beneficial effects of WP on BC or strength. The main findings indicate no effect from WP on strength. Four studies found improvement in BC from WP consumption. Based on the limitations of the studies, more controlled research regarding the overall dietary intake and training protocol is necessary. Based on neural adaptations occurring in the initial stages of RT, WP will not, according to this review's results, accelerate further gains for beginners. More research on individuals experienced with RT and WP is needed considering only two studies explored the effect on experienced individuals. This literature review contributes to future research by highlighting the need for stricter training and diet protocols. Additionally, underscores the need to overcome the limitations resulting from small sample sizes in existing studies.

In conclusion, the results from this narrative literature review reveal limited positive outcomes from combining WP with RT. Furthermore, indications suggest that high-quality protein sources offer similar benefits. Considering the unknown long-term effects of WP, the current literature does not provide sufficient evidence regarding overall health to justify its widespread consumption. In the current literature, there is not enough evidence to demonstrate whether WP is beneficial or unnecessary in combination with RT for young adults.

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