SYSTEMATIC REVIEW/ SİSTEMATİK DERLEME

A SYSTEMATIC REVIEW OF PEA PROTEIN SUPPLEMENTATION AND SPORTS PERFORMANCE

BEZELYE PROTEİNİ TAKVİYESİ VE SPOR PERFORMANSI ÜZERİNE SİSTEMATİK BİR DERLEME

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Received/Geliş tarihi: 18.01.2026 • Accepted/Kabul tarihi: 26.01.2026

ABSTRACT

The global market for protein-based ergogenic aids, a cornerstone of sports nutrition, has experienced significant growth in recent years. While animal-based supplements have traditionally dominated this sector, the rising demand for environmentally friendly and sustainable alternatives has led to a dramatic increase in the popularity of plant-based proteins. The purpose of this systematic review is to evaluate the efficacy of pea protein supplementation in sports performance and to provide a comprehensive perspective on how it differentiates from other protein sources in the literature.

Keywords: Pea protein, Sport performance, Whey protein, Exercise

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INTRODUCTION

Nutrition is an integral part of a healthy life and forms an important part of the sports performance of athletes (1,2). A multidisciplinary approach should be taken when establishing a nutrition routine for athletes. Athlete's meal consumption; it can be revealed through a multidisciplinary study that combines biomechanical, anatomical, physiological, biochemical and of course nutritional sciences (3). Due to this approach, the number of studies on sports nutrition has been increasing in recent years. It is understood that the studies focused especially on high-level competitive athletes (4). One of the components of sports nutrition are nutritional ergogenic aids. In 2022, the global market share of protein supplements exceeded $5.83 billion, and according to Grand View Research's 2023 study, an 8% increase is expected between 2023 and 2030.

An 80% of supplement sales in sports nutrition come from protein or protein-based products (5). The development of functional protein drinks has played an important role in recent years. (6). In addition, with the current demand for environmentally friendly products, research on more sustainable alternative protein sources has also increased (5).

The aim of this review is to emphasize the increase of plant-based proteins due to their positive sustainable and activity effects and to increase the effects of small protein, which stands out in terms of features such as digestibility and amino acid profile, on performance in sports. For subsequent studies and research, the use of pea proteins as supplements provides different perspectives on sports performance and differentiation from other protein supplements. One of the biggest reasons why peas are preferred is that their amino acid profile is similar to other protein sources used.

Proteins

"Proteios" means "Primary" in Ancient Greek (Vickery, 1950), and is translated as "essential nitrogenous element for living beings". It is one of the macronutrients (7). This nomenclature is very appropriate from a nutritional science perspective, this is because protein is considered the most basic component of animal and human tissues. (8).

Proteins are an important nutrient for maintaining good nutrition and health and are essential for the proper functioning of the system. Considering these processes, it ensures growth in childhood, supports muscle and bone metabolism, contributes to the protection of the nervous system, and supports the preservation of muscle mass and physical performance in later life. (9).

Amino acids (AA), which are the smallest structural factors that form proteins (7). AA are the precursors needed for the production of proteins, peptides and low molecular weight substances (e.g. creatine, glutathione, dopamine, serotonin, dopamine, nitric acid, RNA and DNA helicases), which are very essential and of tremendous physiological importance (10,11). Glutamate, glutamine, and aspartate, taken with daily meals, are the main metabolic fuels for the mammalian small intestine during feeding. On the other hand, glutamine in arterial blood is considered the only energy source in the post-absorption state, specifically for this organ (12). ATP is found in lymphocytes and macrophages for the maintenance of the immune system (13). Based on this, AA is needed for the organism's health, growth, development, reproduction, breastfeeding, and survival abilities. This situation has also graphically shown the result of metabolic disorders such as kwashiorkor and marasmus in many children in the world, especially in developing countries (14).

As opposed to protein and amino acid consumption, amino acids are obtained through food consumption and excessive dietary protein intake and/or excessive supplement intake. This may endanger the health of the world, especially in individuals with hepatic or renal dysfunction (15).

Protein Quality and Proteins as Supplements

AA are formed by adding carboxyl and amine groups to many different chemical structures (7). These combinations and amino acid differences distinguish proteins from each other. This is the reason why the use of proteins in the body varies. Focusing here, the term “protein quality” is included.

In nutritional science, the concept of "protein quality" focuses on the relative composition of the amino acids present in a source of protein, comparing them with the protein with the highest quality as a reference, and makes recommendations by scoring these focuses. The Food and Agriculture Organization of the United Nations, together with the World Health Organization and the United States Food and Drug Administration, proposed a method of evaluating proteins according to their quality as of 1991; Protein Digestibility Corrected Amino Acid Score (PDCAAS). This guideline became an official standard in 1993. Although this actually prioritizes digestibility, it also depends on protein absorption kinetics and the stimulating effects of dietary protein on protein synthesis in the organism (16,17).

Subsequently, in 2013, the World Food Organization proposed the Digestible Indispensable Amino Acid Score (DIAAS) as a new evaluation method. This scoring is a more accurate rating of protein quality other than digestibility. When DIAAS and PDCASS are compared; DIASS

obtains its references from the ileum, while PDCAAS obtains its references from the feces. Depending on the amount of amino acids in stool samples, the PDCAAS method accepts digestion as present or absent. However, DIAAS samples obtained from the ileum by separation from here provide a more accurate rating of not only the digestion but also the absorption of the amino acid (18).

It is stated that the amount recommended by the Institute of Medicine (IOM) for daily protein consumption for both male and women aged 19 and over is 0.8 g protein/kg. In the athletic proposals; References for athletes between 70-90 kg for men and 50-70 kg for women are 56-72 g/day for men and 40-56 g/day for women (19). The method that creates daily protein intake recommendations is the balance of nitrogen levels in the body (19,20). Preferring nitrogen balance is a method to determine the amounts of protein, nitrogen or amino acids considered necessary to prevent protein deficiency and maintain nitrogen balance in individuals with a relatively physical activity level and stable body weight. For muscle mass and strength using the same method here; to maximize the gains obtained from resistance training and to maximize the adaptation in metabolic functions, it is possible to consume dietary protein, which is recommended to be taken daily and ensures that the nitrogen balance is at an optimal level. In studies related to protein requirements, final point selection may be evaluated. Although nitrogen balance is a sufficient acceptance point for physically stable individuals, it is a controversial issue for athletes. Based on this, achieving a positive nitrogen balance is a desired goal for those who want to gain lean mass. This developing process probably occurs due to the periodic cessation of muscle protein synthesis. The obvious need for extra amino acids to support net gain from proteins (21).

Animal Based Proteins: Examined and evaluated the effect of nutritional supplements on reducing muscle damage by evaluating some studies in the literature (22,23), oxidative stress (24,25) and improving existing performance (22,26,27). Among these existing nutrients and bioactive compounds, protein ranks first in scientific studies evaluating its effectiveness (28,29). Proteins play many different roles in muscle recovery, including enhancing muscle protein kinetics and mitochondrial biogenesis, activating signaling proteins in the protein synthesis cascade, reducing unwanted inflammatory responses, and contributing to strength recovery (30,31). The main protein source researched in the context of human performance is animal-based sources, whey protein being an example (32). Whey protein is very common as a protein supplement among athletes due to its rich content of branched chain amino acids (BCAAs), its incredibly high amount of leucine, its rapid digestibility and its ability to stimulate

muscle protein synthesis (33). However, plant proteins have taken their place at the forefront in the field of sports sciences by exhibiting serious positive effects on performance and recovery (33,34). Their ability to influence postprandial amino acid profiles and the ability to influence the synthesis of muscle proteins after digestion are also used to describe both plant- and animal-based proteins (35). Due to many of the stated acceptances, results and reasons, plant-based nutrition has recently become very widespread among athletes and has increased its interest.

Plant-Based Proteins: While there are a wide variety of foods for human nutrition, many of them contain protein. When we focus on these proteins, complete protein sources are preferred, which will meet the needs at the cellular level while providing sufficient essential amino acids (36).

The fact that animal-based protein sources increase sports performance is widely accepted and prevalent in the literature. However, the need for alternatives that contain clean ingredients and do not react to allergies and intolerances is increasing. While the importance of sustainability increases, concerns about animal welfare and ethics increase interest in alternative solutions to existing proteins (37,38).

Choosing plant-derived proteins not only meets individual needs and desires, but also has an impact on preventing many diseases. Choosing plant-based foods to protect against cancer, Type 2 Diabetes and cardiovascular diseases can be very effective in reducing these risks (39). In addition, from an economic perspective, meeting the protein needs of the society with local products can be a much more cost-effective method. At the last point, when we look at the world in general, it is known that 60% of the daily protein intake is of plant origin and 4 billion world citizens are primarily turning to plant-based nutrition (40).

Pea Protein: The interest and need for different proteins have increased in the last 15 years. They were influenced by the powder and bar forms of proteins and whether they were vegan or vegetarian, and focused more on the feeling of individual power that depended on this. While soy and already standardized whey protein were used as herbal sources in previous processes, the popularity of other herbal sources has increased day by day. When we look at plant-based diets, it has been observed that it decreases with high blood pressure and impaired blood glucose that is not genetically inherited but is affected by environmental factors. Based on this response, other individuals have also turned to plant-based proteins (41). When we look at these sources, pea proteins, which are not affected by the 8 most common allergens (milk, eggs, peanuts, tree nuts, soy, fish, mollusks, and wheat) come to the fore. Pea protein can also be obtained through physical dissolution, not chemical dissolution like whey or soy protein. This ensures the

preservation of many soluble fiber structures. Pea protein has a high amount of lysine amino acid. Lysine is also a precursor of the fat transporter carnitine and is indispensable for immune elements (42,43). Peas also contain less heme iron than many sources with high iron content and have a higher amount of usable iron. Of course, with proper nutrition recommendations, the absorption rate of lactic acid and ascorbic acid increases (41). Pea proteins obtained from yellow peas, scientifically known as Pisum Sativum, it is a protein isolate that contains 85% of the proteins and is rich in branched chain amino acids (leucine, isoleucine, valine), which are essential and play an important role in muscle protein synthesis (44). In recent scientific studies, it has been determined that pea proteins are of similar quality to soy and egg and are better than other plant protein sources (45,46). Pea protein, found in pea seeds; It is a plant-based source that contains four main protein classes (globulin, albumin, prolamin and glutelin), of which globulin and albumin are the main storage proteins, and is considered a high-quality protein (47). Pea protein contains essential amino acids such as methionine and cysteine, which are limited only by the sulfur amino acid content (48, 49), and appears to be a source of small peptides in a bioactive state (50). Targeted analysis of biochemical markers related to immune and antioxidant systems and cell and tissue damage, and evaluation of exercise and nutritional interventions may be a promising approach for the future. In fact, evaluation of the non-targeted metabolite profile can provide a much more comprehensive understanding of the general metabolic status of individual athletes (51).

Muscle Protein Synthesis and Resistance Training: Hypertrophy

The effects of protein synthesis on muscles have long been an indispensable research topic in sports and nutrition sciences. With these studies, it is seen that protein synthesis metabolism affects both training and non-training individuals for up to 48 hours after training (52). Proteins are synthesized and broken down simultaneously in muscles. Catabolic processes are accompanied by anabolic processes, and hypertrophy of the muscles occurs due to the negative net protein balance (53). Myofibrillar protein transformation appears to be a slow turnover under the influence of resistance exercises (54,55).

This slow turnover requires a relatively long period of time, such as 6-8 weeks, for resistance exercise to cause changes in muscle fiber type, increase the fiber diameter, and allow an outward change in the phenotype, resulting in muscle fiber type development and hypertorphia (55-57). In the case of resistance exercises, we find out that it does not cause an acute increase in protein turnover or oxidation during exercise, but the post-exercise period is the period when changes in muscle protein turnover, specifically an increase in muscle protein synthesis, occur (58).

METHOD

Systematic Review Strategy

The keywords "pea protein" and "sports performance", "pea protein" and "exercise" were searched in English in Scopus, Web of Sciences, SPORTDiscus with Full Text and PubMed databases. References of the selected studies were also manually checked to identify studies that may have been missed in the search (59). It was decided to include the studies identified in the research conducted.

A total of 220 articles were accessed, 95 in the Scopus database, 74 in the Web of Sciences database, 6 in the SPORTDiscus with Full Text database, and 45 in the Pubmed database. The scans cover the years 2014-2024. In the first research, duplicate studies were removed and a total of 131 articles were reached and transferred to the bibliographic management software (Mendeley, 1.19.8). After this stage, article titles and abstracts were scanned for suitability. Only research articles and studies in the field of sports sciences were included in the study, and 13 studies were reached by removing studies with insufficient citation information, food engineering studies, agricultural sciences studies, nutritional sciences and studies that were not research articles. Then, by applying justified exclusion criteria, studies involving only human participants were filtered in the methods section, and "10" studies were included in the systematic review.

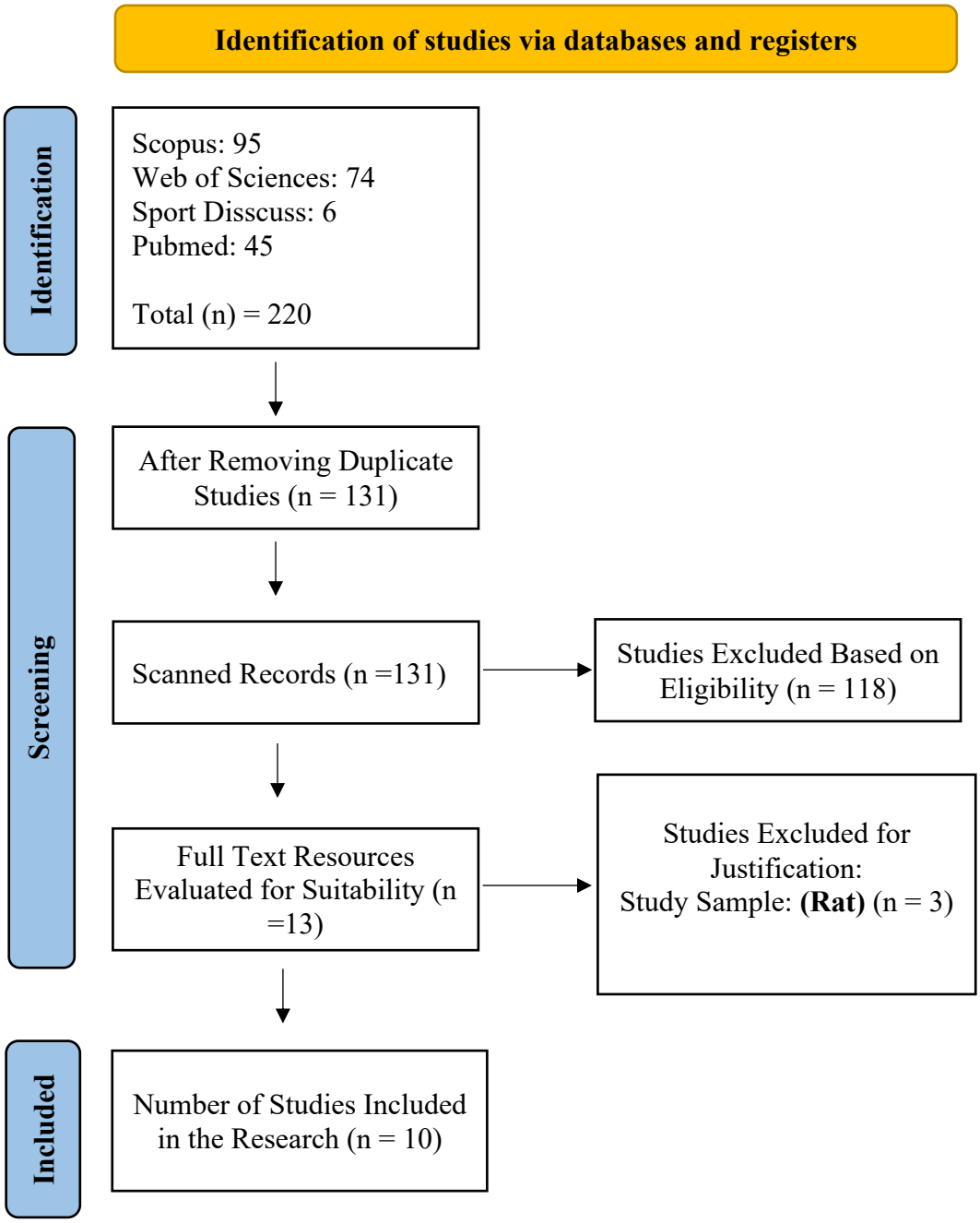

Figure 1. Systematic Review Strategy (PRISMA)

Table 1. Pea Proteins and Sport Performance Effect

Study	Group	Method	Results
Lanng et al. 2023	52 Young Men	- A leg extension resistance exercise (Maximum 10 repetitions, 4 x 10) training program has been prepared. - Afterwards, cricket (insect), pea or whey protein was consumed. Supplements were given at 0.25 g protein per kilogram of lean mass. - Blood and muscle tissue were collected at the first consumption of protein (baseline) and three hours after protein intake. Urine samples were collected at baseline and four hours after protein intake. - Mixed effects analyzes were applied to examine the effect of time (baseline and post), protein (cricket, pea, whey), and time x protein interaction.	- Muscle concentrations of leucine, methionine, glutamate, and myoinositol were found to be higher after whey protein intake compared to both cricket and pea protein. - The concentration of trimethylamine N-oxide in urine after cricket intake was significantly higher than that of pea and whey protein.

Study	Group	Method	Results
Coutinho et al. 2014	24 Soldiers	- The 24 soldiers in the Brazilian Army are divided into three equal groups. (n=8). - Soldiers who underwent the Leader's Reaction Test received reinforcement immediately after the test, at 60 minutes, and at 120 minutes. These supplements; carbohydrate (0.8 g/kg body weight/hour), carbohydrate + carbohydrate (1.0 g/kg body weight/hour) or carbohydrate + pea protein (0.8 g/kg body weight/hour carbohydrate + 0.2 g /kg body weight/hour protein). - Soldiers' maximal isometric strength and body composition were evaluated before, immediately after, and 24 hours after the Leader's Reaction Test. - Afterwards, blood samples are collected; Lactate dehydrogenase and creatine kinase concentrations were evaluated.	- Creatine kinase levels measured 24 hours after the Leader's Reaction Test were found to be significantly lower in soldiers taking pea protein supplements than those measured immediately afterwards.

Study	Group	Method	Results
Ahmad et al. 2020	28 Male Between the ages of 19 – 29	- 28 men were equally divided into four groups. - Plant-based group combined with resistance training, plant-based protein only, resistance training only and control group were determined. - Resistance training was planned as barbell press, machine shoulder press, wide grip lateral pull, seated cable row, barbell back squat, leg press and leg extension. - 8-week resistance training consists of three sets of maximum 60-70% single repetition (1-RM) in 4-6 repetitions/set/mode each, three times a week. - Pea and soy blended vegetable protein support was provided to protein consuming groups.	- The trained and protein group showed a significant increase in knee and shoulder flexion compared to the training-only group ($p<0.01$). - Blood urea nitrogen (BUN) and serum urea levels were found to be significantly higher in the group receiving only vegetable protein supplements compared to the other groups ($p<0.05$).

Study	Group	Method	Results
Loureiro et al. 2023	12 Male Football Players Under 20	- For 10 days, each participant took 0.5 g/kg of pea or whey protein supplements after training, starting 7 days before the experimental day and continuing until 2 days after. - After a 4-day break, the athletes were transferred to opposing groups and the intervention was restarted. - Blood samples were taken before, after, and at intervals of 24 hours, 48 hours, and 72 hours after the experimental matches. Creatine kinase, aspartate transaminase, alanine transaminase, lactate, urea, creatinine, and uric acid parameters were analyzed with commercial kits. - Exploratory metabolic profiling of serum samples were performed by nuclear magnetic resonance spectroscopy.	- It was observed that the pea protein group had lower creatine kinase at the 24th and 48th hours after the experiment. - In the whey protein group, glutamate and lactate levels differed significantly between pre-experiment and post-experiment measurements. - After the experiment, while there was a decrease in metabolites such as arginine and taurine in the whey protein group, no such difference was observed in the pea protein group.

Study	Group	Method	Results
Saracino et al. 2020	27 Male Recreationally active, Middle-aged	- In the morning, 5 sets of 15 repetitions of maximal eccentric voluntary contractions were performed for the knee extensors and flexors, respectively. - They were divided into 4 groups and supplemented with 40 g of whey protein hydrolysate, whey protein isolate, rice and pea protein and placebo daily, on the training day and the next two nights. - Diets were standardized and daily foods were planned (15% protein, 55% carbohydrates and 30% fat). - Plasma creatine kinase, interleuktin-6 and interleuktin-10 were measured immediately before, immediately after, and at 4, 6, 24, 48 and 72 hours after training. - Isometric and isokinetic maximum voluntary contraction forces were measured at the same measurement moments. - Muscle pain, thigh circumference and HOMA-IR values were evaluated before the match, at 24, 48 and 72 hours.	- Creatine kinase increased at 4 hours post-training ($p < 0.001$) and reached highest levels at 72 hours ($p < 0.001$). - Among the results, there was no significant difference between the groups in terms of any measurement.

Study	Group	Method	Results
Nieman et al. 2020	92 Male Between the ages of 18 – 55	- Whey, pea proteins (0.9 g protein/kg, divided into three doses per day) and water (placebo) were supplemented. - It was tested on muscle damage, inflammation, delayed onset of muscle soreness (DOMS), and physical fitness test performance with a 90-minute eccentric training session for 5 days. - Eccentric exercise caused muscle damage and pain. Bench press and 30-second Wingate performance decreased.	- While there was no significant difference between pea protein and whey protein in creatine kinase and myoglobin markers, their effects were significant only against water. - Whey protein intake for 5 days after intense eccentric exercise attenuated the flux of muscle damage biomarkers, with a moderate effect seen in the pea protein intake group.

Study	Group	Method	Results
Lanng et al. 2022	- 50 Male Between the ages of 18 – 30	- The young men were divided into three groups to do single-leg resistance exercise, and each was supplemented with either cricket, pea or whey protein. - Blood samples were collected for 4 hours following protein ingestion at seven fixed time points (20, 40, 60, 90, 120, 180, 240 minutes). - A muscle biopsy was taken 3 hours after protein ingestion from both the exercised leg and the non-exercise leg, as well as a baseline sample before exercise and protein ingestion. - Blood insulin and Dual-energy X-ray absorptiometry (DXA) evaluations were made.	- Blood serum analysis showed a significantly higher concentration of amino acids after ingestion of whey protein compared to cricket and pea protein. - No differences between protein sources were observed in activation of the mTORC1 signaling pathway at rest or after exercise.

Study	Group	Method	Results
Babault et al. 2014	- 161 Male Between the ages of 18 – 35	- Participants were divided into 3 groups and added to the training. These three groups were determined as those who consumed whey protein, those who consumed pea protein, and those who consumed placebo. - All were scheduled to receive 25 grams of protein or a placebo twice a day for the 12-week training period. - Tests were performed on the biceps muscles on the inclusion day (D0), mid-day (D42) and post-training day (D84). Muscle thickness was assessed using ultrasonography and strength was measured with an isokinetic dynamometer.	- The results showed a significant time effect for biceps brachii muscle thickness. There was only a trend towards significant differences between groups (P = 0.09). - When a sensitivity study was conducted on the leanest participants (in terms of power of inclusion), thickness increases appeared to be significantly different between groups. - Increases in thickness were significantly greater for the Pea group compared to placebo. However, no difference was observed between Whey and the other two conditions. Muscle strength also increased over time, with no statistical difference between groups.

Study	Group	Method	Results
Spoelder et al. 2023	- 47 Physically Active Elder 60+ Years	- Participants were randomly divided into 3 groups. These groups; determined as whey protein (25 g/day), pea protein (25 g/day) and isocaloric placebo. - Blood concentrations of creatine kinase (CK) and lactate dehydrogenase (LDH) and skeletal muscle mass, muscle strength and muscle soreness were measured before and 24 hours, 48 hours and 72 hours after a long-distance walk (20-30 km).	- Whey group; showed a significant reduction in EIMD increase at 24 h after exercise compared to the pea and placebo group. - No differences were observed between groups in terms of LDH levels, muscle strength, skeletal muscle mass and muscle pain (all p values > 0.05).

Study	Group	Method	Results
Banaszek et al. 2019	- 15 HIFT Men	- Participants were divided into two groups and given pea and whey protein supplements. Participants were provided with 24 grams of protein supplement. Individuals were exposed to 8 weeks of HIFT training 4 times a week. - Before the training, muscle thickness, bioelectrical impedance analysis (BIA), two-reference WOD (training of the day), 1 Repetition Maximum (1RM) squat and deadlift test and Isometric Mid-Thigh Pull (IMTP) measurements were performed. - Separate analyzes of covariance (ANCOVA) were performed on all measurements collected at POST.	- Increased strength differences were observed for the 1RM back squat ($p = 0.006$) and deadlift ($p = 0.008$) in both groups. - No training effects ($p > 0.05$) were found in terms of body composition, muscle thickness, IMTP peak strength, IMTP force development rate, or performance in either WOD. - When PRE values were used as covariates, no group differences occurred for any measured variable.

DISCUSSION

The purpose of this review article is to examine the relationship between pea proteins and sports performance. The effects of proteins on muscle development and performance have maintained their place in the literature for a long time. Considering the new protein sources and the differing effects of protein sources according to other developing conditions, pea protein as a different source appears as a quality alternative.

In a study conducted by Coutinho et al. in Brazil, 24 soldiers were divided into 3 groups and after the Leadership Reaction Test, the soldiers; They consumed the supplements immediately after, 60 minutes, and 120 minutes later. These supplements; carbohydrate (0.8 g/kg body weight/hour), carbohydrate + carbohydrate (1.0 g/kg body weight/hour) or carbohydrate + pea

protein (0.8 g/kg body weight/hour carbohydrate + 0.2 g/kg body weight/hour protein). Soldiers' maximum isometric strength and body composition were evaluated before, immediately after and 24 hours after the test. The most notable result of the group consuming the combination of pea protein and carbohydrates was that their Creatine Kinase (CK) levels were significantly reduced within 24 hours of the test (60). While it is stated that CK is a very important blood parameter for muscle damage and recovery, unlike other groups, decreases were observed in the group consuming pea protein and carbohydrates (61).

Lazarim et al. (62) mentioned its use as part of plasma CK activity analysis as an early parameter for muscle overload and fatigue in football players; By determining an upper limit for CK activity and measuring players according to this value, it ensures physical protection and optimizes training programs accordingly. An increase in athletes' performance is expected with protection below the CK upper limit (62). To evaluate whether plant-based protein would benefit the recovery of athletes, Kritikos (61) investigated the effect of WP and Soy Protein supplementation in football players up to 48 hours after physical testing. According to their results, it revealed no differences between groups in CK and muscle soreness (for all time points). Evaluating the effect of soy protein supplementation for four weeks in a training protocol that caused muscle damage in trained volunteers, Shenoy found lower levels of CK and C-reactive protein in the supplemented group than in the placebo group (63). Compared with soy protein, PP is characterized by its high digestibility and has relatively fewer allergic responses (64), and PP is a relatively new type of vegetable protein. It is becoming more and more popular in the food industry due to its availability, low cost, nutritional value, and health benefits (47). Based on the nutritional quality of PP, Babault (65), compared the effects of daily supplementation with WP, PP, and placebo after 12 weeks of strength training. The results showed a significant increase over time for biceps brachii muscle thickness, but no significant difference trended between groups. The pea group showed significant increases in muscle thickness compared to placebo, but no differences were observed between whey protein and the other two conditions, and muscle strength increased over time, but no statistical difference was found between groups. Banaszek (33), conducted a single comparative study of protein sources to evaluate muscle recovery in Crossfit athletes. 15 HIFT male participants were divided into two groups and the participants were given pea and whey protein supplements for 8 weeks. During these 8 weeks, HIFT training was performed 4 times a week. No training effects were found on body composition, muscle thickness, IMTP Peak Power, IMTP force development rate, or WOD performance. When PRE values were used as covariates, no group

differences were observed in the measured variables. Findings from a double-blind, crossover and randomized study by Loureiro supported that PP could replace WP. 12 male football players under the age of 20 were trained starting 7 days before the experiment day and continuing until 2 days after the experiment and received 0.5 g/kg pea or whey protein supplements after the training. Although post-game CK and ALT values were lower in the PP group, the difference was detected only in the delta analysis. The lack of significant differences between some groups shows that the metabolic changes found are not sufficient to distinguish the response to fatigue or muscle damage in the short term, and it does not seem possible to directly say that PP supplementation is superior to WP in the recovery process of athletes. Additionally, when it comes to these changing metabolites, after the experiment, a decrease in arginine and taurine was observed in the whey protein group, while no such difference was observed in the pea protein group (66).

In the studies subject to this article, no significant result differences were found between whey and pea proteins, and these articles actually stated that pea protein can be used instead of whey protein (33, 67-69).

In another pea protein study, 47 physically active elderly individuals over the age of 60 were randomly divided into three groups; whey protein (25 g/day), pea protein (25 g/day), and isocaloric placebo supplements were provided. The whey group showed a significant reduction in EIMD elevation 24 hours after exercise compared to the pea and placebo groups. There were no differences between groups in terms of LDH levels, muscle strength, skeletal muscle mass and muscle pain (70).

In a study where pea proteins were used together with soy proteins, 28 men aged 19-29 were divided into four groups and followed as plant-based protein + resistance training, plant-based protein only, resistance training only and control group. Resistance training was planned as three sets with a maximum of 60-70% 1-RM three times a week for 8 weeks, and protein consuming groups were given plant-based protein supplements with a mixture of peas and soy. The training and protein group showed significant increases in knee and shoulder flexion compared to the training only group. In the group that took only plant-based protein supplements, blood urea nitrogen (BUN) and serum urea levels were found to be significantly higher than the other groups (71).

In a study focusing on the effects of pre-sleep whey protein and plant-based protein consumption on muscle recovery, 27 middle-aged, recreationally active men were divided into four groups to train their knee extensors and flexors in the morning for 5 sets of 15 repetitions

with maximum eccentric voluntary contractions on the training day and the next two. supplemented with 40 g daily of whey protein hydrolyzed, whey protein isolate, rice and pea protein, and placebo overnight. Their diets are standardized, and daily menus are planned (15% protein, 55% carbohydrates and 30% fat). Plasma creatine kinase increased 4 hours after training. Isometric and isokinetic maximum eccentric voluntary contraction forces, muscle pain, thigh circumference and HOMA-IR values were evaluated and no significant difference was found in any of the measurements between the groups (72).

In this study, which focused on the effects of whey protein and pea protein supplements on muscle damage after eccentric exercise, participants were given whey, pea proteins (0.9 g protein/kg, divided into three doses per day) and water (placebo) as supplements. No significant differences were found between 90-minute eccentric training over five days and whey and pea proteins in terms of creatine kinase and myoglobin markers, but their effects were significant only versus water. Whey protein intake after five days of intense eccentric training attenuated the flux of muscle damage biomarkers, with a moderate effect observed in the group consuming pea protein (73).

The focus of the studies conducted by Lanng at two different times was to compare cricket, whey and pea proteins with each other. In the study conducted in 2022, 50 men between the ages of 18-30 were divided into three groups, performed single-leg resistance exercise, and were divided into 3 groups (those who took cricket, pea or whey protein supplements). Amino acid concentration in blood serum after whey protein intake was found to be higher than cricket and pea protein. However, no difference in the activation of the mTORC1 signaling pathway was observed between protein sources (74).

In the study conducted in 2023, in this pea protein study, individuals who underwent leg extension resistance exercise; cricket (insect), pea protein and whey protein supplements were given at 0.25 g protein per kilogram. In this study; Muscle concentrations of leucine, methionine, glutamate, and myoinositol were higher after whey protein intake compared to both cricket and pea protein, while urinary N-oxide concentration was significantly higher after cricket intake than in those consuming pea and whey protein (75).

CONCLUSION AND RECOMMENDATIONS

While studies on pea protein are promising, they also contain conflicting results. In the future, the effects of combined use of whey and pea protein or the use of both at different times in the same week as ergogenic supplements for different workouts may also produce effective results.

When pea protein is examined in future research, it may have effects on recovery and providing advantages while individualizing the training schedule. While investigating the effects of pea proteins on blood, CK and LDH, examining hormonal balances in connection with these may create a different parameter for us. Such studies can provide a comprehensive perspective to understand the potential benefits that will improve athletes' performance.

Since male individuals, young, middle-aged, and middle-aged individuals were examined in the articles examined within the scope of this review, observing its effects on recovery and hormonal balance for women and female athletes will yield possible beneficial results. Considering the ease of intestinal passage of pea protein and its absorption in the intestinal villi, it may be beneficial to observe the duration of action and the developmental process. Comparing different based protein sources such as pea protein and casein can lead us to a process where we can turn the disadvantages of casein in favor of the athlete. Although there is no significant difference between pea protein and whey protein, it can be much more useful for athletes with special preferences or obligations, such as vegans, ovo vegetarians, individuals with lactose intolerance, while increasing sports performance. It is more easily accessible because it is a plant-based agricultural product that is easy to produce and highly productive in many parts of the world. This easy accessibility, in the same way, emerges as a sustainable, environmentally friendly and beneficial, natural and economical product. This can be a powerful alternative product in performance enhancing methods.

Abbreviations

CK: Creatine Kinase

PDCAAS: Protein Digestibility Corrected Amino Acid Score

AA: Amino Acids

DXA: Dual-energy X-ray absorptiometry

DIAAS: Digestible Indispensable Amino Acid Score

Conflict of interest: The authors declare that there are no conflicts of interest.

Funding sources: No fund support was received for this research.

Author contributions: Design: YA; Methodology implementation: YA, DA; Manuscript writing: YA, DA.

REFERENCES

1. Vuori IM. Health benefits of physical activity with special reference to interaction with diet. Public Health Nutr. 2001;4:517–28.
2. Walker KZ, ODea K, Gomez M, Girgis S, Colagiuri R. Diet and exercise in the prevention of diabetes. J Hum Nutr Diet. 2010;23:344–52.
3. Balagué N, Torrents C, Hristovski R, Kelso J. Sport science integration: An evolutionary synthesis. Eur J Sport Sci. 2017;17:51–62.
4. Maughan RJ, Shirreffs SM. Nutrition for sports performance: issues and opportunities. Proc Nutr Soc. 2012;71:112–9.
5. Arenas-Jal M, Suñé-Negre JM, Pérez-Lozano P, García-Montoya E. Trends in the food and sports nutrition industry: A review. Crit Rev Food Sci Nutr. 2020;60:2405–21.
6. Orrù S, Imperlini E, Nigro E, Alfieri A, Cevenini A, Polito R, et al. Role of functional beverages on sport performance and recovery. Nutrients. 2018;10:1470.
7. Baysal A. Beslenme. Hatiboğlu Yayınevi 2004.
8. Tomé D. Digestibility issues of vegetable versus animal proteins: protein and amino acid requirements—functional aspects. Food Nutr Bull. 2013;34:272–4.
9. Watford M, Wu G. Protein. Adv Nutr. 2018;9:651–3.
10. San Gabriel A, Uneyama H. Amino acid sensing in the gastrointestinal tract. Amino Acids. 2013;45:451–61.
11. Wu G. Amino acids: metabolism, functions, and nutrition. Amino Acids. 2009;37:1–17.
12. Reeds PJ, Burrin DG, Stoll B, van Goudoever JB. Role of the gut in the amino acid economy of the host. Nestle Nutr Workshop Ser Clin Perform Programme. 2000;3:25–40.
13. Li P, Yin YL, Li D, Kim SW, Wu G. Amino acids and immune function. Br J Nutr. 2007;98:237–52.
14. FAO. Dietary protein evaluation in human nutrition. FAO Food Nutr Pap. 2013;92:1–66.
15. Hoffer LJ, Bistrian BR. Appropriate protein provision in critical illness: a systematic and narrative review. Am J Clin Nutr. 2012;96:591–600.
16. Marriott BP, Birt DF, Stallings VA, Yates AA. Present knowledge in nutrition: basic nutrition and metabolism. Academic Press 2020.
17. Trommelen J, Tomé D, van Loon LJ. Gut amino acid absorption in humans: concepts and relevance for postprandial metabolism. Clin Nutr Open Sci. 2021;36:43–55.

18. FAO Expert Consultation. Dietary protein quality evaluation in human nutrition. FAO Food Nutr Pap. 2011;92:1–66.
19. Trumbo P, Schlicker S, Yates AA, Poos M. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. J Am Diet Assoc. 2002;102:1621–31.
20. Rand WM, Pellett PL, Young VR. Meta-analysis of nitrogen balance studies for estimating protein requirements in healthy adults. Am J Clin Nutr. 2003;77:109–27.
21. Phillips SM. Dietary protein requirements and adaptive advantages in athletes. British Journal of Nutrition. 2012;108(S2):S158-S67.
22. Ammar A, Bailey SJ, Chtourou H, Trabelsi K, Turki M, Hökelmann A, Souissi N. Effects of pomegranate supplementation on exercise performance and post-exercise recovery in healthy adults: a systematic review. Br J Nutr. 2018;120:1201–16.
23. Parsaie N, Ghavamzadeh S, Cheraghi M. Effects of cholecalciferol supplementation on inflammatory markers and muscle damage indices of soccer players after a simulated soccer match. Nutrition. 2019;59:37–43.
24. Jówko E, Sadowski J, Długołęcka B, Gierczuk D, Opaszowski B, Cieśliński I. Effects of Rhodiola rosea supplementation on mental performance, physical capacity, and oxidative stress biomarkers in healthy men. J Sport Health Sci. 2018;7:473–80.
25. Orlando P, Silvestri S, Galeazzi R, Antonicelli R, Marcheggiani F, Cirilli I, et al. Effect of ubiquinol supplementation on biochemical and oxidative stress indexes after intense exercise in young athletes. Redox Rep. 2018;23:136–45.
26. Apostolidis A. Caffeine supplementation: ergogenic effects across exercise intensities. Int J Sport Physiol Perform. 2019;14.
27. Hsu TH, Chiu CC, Wang YC, Chen TH, Chen YH, Lee YP, et al. Supplementation with beef extract improves exercise performance and reduces post-exercise fatigue independent of gut microbiota. Nutrients 2018;10:1740.
28. Jäger R, Kerksick CM, Campbell BI, Cribb PJ, Wells SD, Skwiat TM, et al. International society of sports nutrition position stand: protein and exercise. J Int Soc Sports Nutr. 2017;14:20.
29. Torre-Villalvazo I, Alemán-Escondrillas G, Valle-Ríos R, Noriega LG. Protein intake and amino acid supplementation regulate exercise recovery and performance through the modulation of mTOR, AMPK, FGF21, and immunity. Nutr Res. 2019;72:1–17.

30. Cintineo HP, Arent MA, Antonio J, Arent SM. Effects of protein supplementation on performance and recovery in resistance and endurance training. Front Nutr. 2018;5:400140.
31. Forbes SC, Candow DG, Smith-Ryan AE, Hirsch KR, Roberts MD, VanDusseldorp TA, et al. Supplements and nutritional interventions to augment high-intensity interval training physiological and performance adaptations—A narrative review. Nutrients. 2020;12:390.
32. Lam FC, Bukhsh A, Rehman H, Waqas MK, Shahid N, Khaliel AM, et al. Efficacy and safety of whey protein supplements on vital sign and physical performance among athletes: A network meta-analysis. Front Pharmacol. 2019;10:317.
33. Banaszek A, Townsend JR, Bender D, Vantrease WC, Marshall AC, Johnson KD. The effects of whey vs. pea protein on physical adaptations following 8-weeks of high-intensity functional training (HIFT): A pilot study. Sports. 2019;7:12.
34. Berrazaga I, Micard V, Gueugneau M, Walrand S. The role of the anabolic properties of plant-versus animal-based protein sources in supporting muscle mass maintenance: a critical review. Nutrients. 2019;11:1825.
35. Kerksick CM, Jagim A, Hagele A, Jäger R. Plant proteins and exercise: what role can plant proteins have in promoting adaptations to exercise? Nutrients. 2021;13:1962.
36. Phillips SM, Chevalier S, Leidy HJ. Protein requirements beyond the RDA: implications for optimizing health. Appl Physiol Nutr Metab. 2016;41:565–572.
37. Meiselman HL. Handbook of eating and drinking. Springer. 2020.
38. Radnitz C, Beezhold B, DiMatteo J. Investigation of lifestyle choices of individuals following a vegan diet for health and ethical reasons. Appetite. 2015;90:31–36.
39. Lynch H, Johnston C, Wharton C. Plant-based diets: considerations for environmental impact, protein quality, and exercise performance. Nutrients. 2018;10:1841.
40. Grünberger K. Estimating food consumption patterns by reconciling food balance sheets and household budget surveys. Food and Agriculture Organization of the United Nations. 2014.
41. Krefting J. The appeal of pea protein. J Ren Nutr. 2017;27:e31–3.
42. Rhodes DG, Morton S, Martin CL, Adler ME, Hymes MA, Garceau AO, et al. 2016 food and nutrient database for dietary studies. US Department of Agriculture Agricultural Research Service 2018.
43. Ruscigno M. Pea protein. Todays Dietitian 2016;18:32.

44. Stark M, Lukaszuk J, Prawitz A, Salacinski A. Protein timing and its effects on muscular hypertrophy and strength in individuals engaged in weight-training. J Int Soc Sports Nutr. 2012;9:54.

45. Asgar MA, Fazilah A, Huda N, Bhat R, Karim AA. Nonmeat protein alternatives as meat extenders and meat analogs. Compr Rev Food Sci Food Saf. 2010;9:513–29.

46. World Health Organization, United Nations University. Protein and amino acid requirements in human nutrition. World Health Organization 2007.

47. Lam ACY, Karaca AC, Tyler RT, Nickerson MT. Pea protein isolates: structure, extraction, and functionality. Food Rev Int. 2018;34:126–47.

48. Nelson AR, Jackson L, Clarke J, Stellingwerff T, Broadbent S, Rowlands DS. Effect of post-exercise protein–leucine feeding on neutrophil function, immunomodulatory plasma metabolites and cortisol during a 6-day block of intense cycling. Eur J Appl Physiol. 2013;113:2211–22.

49. Rowlands DS, Nelson AR, Raymond F, Metairon S, Mansourian R, Clarke J, et al. Protein-leucine ingestion activates a regenerative inflammo-myogenic transcriptome in skeletal muscle following intense endurance exercise. Physiol Genomics. 2016;48:21–32.

50. Shanthakumar P, Klepacka J, Bains A, Chawla P, Dhull SB, Najda A. The current situation of pea protein and its application in the food industry. Molecules. 2022;27:5354.

51. Prado E, Souza GH, Pegurier M, Vieira C, Lima-Neto ABM, Assis M, et al. Non-targeted sportomics analyses by mass spectrometry to understand exercise-induced metabolic stress in soccer players. Int J Mass Spectrom. 2017;418:1–5.

52. Phillips SM, Tipton KD, Aarsland ASLE, Wolf SE, Wolfe RR. Mixed muscle protein synthesis and breakdown after resistance exercise in humans. Am J Physiol Endocrinol Metab. 1997;273:E99–E107.

53. Biolo G, Maggi SP, Williams BD, Tipton KD, Wolfe RR. Increased rates of muscle protein turnover and amino acid transport after resistance exercise in humans. Am J Physiol Endocrinol Metab. 1995;268:E514–20.

54. Hortobágyi T, Dempsey L, Fraser D, Zheng D, Hamilton G, Lambert J, Dohm L. Changes in muscle strength, muscle fibre size and myofibrillar gene expression after immobilization and retraining in humans. J Physiol. 2000;524:293–304.

55. Staron RS, Karapondo DL, Kraemer WJ, Fry AC, Gordon SE, Falkel JE, et al. Skeletal muscle adaptations during early phase of heavy-resistance training in men and women. J Appl Physiol. 1994;76:1247–55.

56. Green H, Goreham C, Ouyang J, Ball-Burnett M, Ranney D. Regulation of fiber size, oxidative potential, and capillarization in human muscle by resistance exercise. Am J Physiol Regul Integr Comp Physiol. 1999;276:R591–6.

57. McCall GE, Byrnes WC, Dickinson A, Pattany PM, Fleck SJ. Muscle fiber hypertrophy, hyperplasia, and capillary density in college men after resistance training. J Appl Physiol. 1996.

58. Tarnopolsky MA, Atkinson SA, MacDougall JD, Senor BB, Lemon PW, Schwarcz H. Whole body leucine metabolism during and after resistance exercise in fed humans. Med Sci Sports Exerc. 1991;23:326–33.

59. Moher D, Liberati A, Tetzlaff J, Altman DG, Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg. 2010;8:336–341.

60. Coutinho LAA, Cerqueira LS, Rodrigues AVS, Porto CPM, Pierucci APTR. Co-ingestion of carbohydrate and pea protein does not enhance muscle recovery after strenuous exercise. Rev Nutr. 2014;27:367–77.

61. Kritikos S, Papanikolaou K, Draganidis D, Poulios A, Georgakouli K, Tsimeas P, et al. Effect of whey vs. soy protein supplementation on recovery kinetics following speed endurance training in competitive male soccer players: a randomized controlled trial. J Int Soc Sports Nutr. 2021;18:23.

62. Lazarim FL, Antunes-Neto JM, Da Silva FO, Nunes LA, Bassini-Cameron A, Cameron LC, et al. The upper values of plasma creatine kinase of professional soccer players during the Brazilian National Championship. J Sci Med Sport. 2009;12:85–90.

63. Shenoy S, Dhawan M, Sandhu JS. Four weeks of supplementation with isolated soy protein attenuates exercise-induced muscle damage and enhances muscle recovery in well trained athletes: a randomized trial. Asian J Sports Med. 2016;7:e33528.

64. Lu ZX, He JF, Zhang YC, Bing DJ. Composition, physicochemical properties of pea protein and its application in functional foods. Crit Rev Food Sci Nutr. 2020;60:2593–2605.

65. Babault N, Païzis C, Deley G, Guérin-Deremaux L, Saniez MH, Lefranc-Millot C, Allaert FA. Pea proteins oral supplementation promotes muscle thickness gains during resistance training: a double-blind, randomized, placebo-controlled clinical trial vs whey protein. J Int Soc Sports Nutr. 2015;12:3.

66. Loureiro LL, Ferreira TJ, Cahuê FLC, Bittencourt VZ, Valente AP, Pierucci APTR. Comparison of the effects of pea protein and whey protein on the metabolic profile of soccer athletes: a randomized, double-blind, crossover trial. Front Nutr. 2023;10:1210215.

67. Lanng SK, Oxfeldt M, Pedersen SS, Johansen FT, Risikesan J, Lejel T, et al. Influence of protein source (cricket, pea, whey) on amino acid bioavailability and activation of the mTORC1 signaling pathway after resistance exercise in healthy young males. Eur J Nutr. 2023;62:1295–1308.

68. Nieman DC, Zwetsloot KA, Simonson AJ, Hoyle AT, Wang X, Nelson HK, et al. Effects of whey and pea protein supplementation on post-eccentric exercise muscle damage: a randomized trial. Nutrients. 2020;12:2382.

69. Saracino PG, Saylor HE, Hanna BR, Hickner RC, Kim JS, Ormsbee MJ. Effects of pre-sleep whey vs plant-based protein consumption on muscle recovery following damaging morning exercise. Nutrients. 2020;12:2049.

70. Spoelder M, Koopmans L, Hartman YA, Bongers CC, Schoofs MC, Eijsvogels TM, Hopman MT. Supplementation with whey protein, but not pea protein, reduces muscle damage following long-distance walking in older adults. Nutrients. 2023;15:342.

71. Ahmad AH, Ong MLY, Ooi FK. Combined effects of plant-based protein supplementation with 8-week resistance training on muscular strength, protein catabolism, immune functions and bone metabolism markers in adult males. 2020.

72. Saracino PG, Saylor HE, Hanna BR, Hickner RC, Kim JS, Ormsbee MJ. Effects of pre-sleep whey vs plant-based protein consumption on muscle recovery following damaging morning exercise. Nutrients. 2020;12:2049.

73. Nieman DC, Zwetsloot KA, Simonson AJ, Hoyle AT, Wang X, Nelson HK, et al. Effects of whey and pea protein supplementation on post-eccentric exercise muscle damage: a randomized trial. Nutrients. 2020;12:2382.

74. Lanng SK, Oxfeldt M, Pedersen SS, Johansen FT, Risikesan J, Lejel T, et al. Influence of protein source (cricket, pea, whey) on amino acid bioavailability and activation of the mTORC1 signaling pathway after resistance exercise in healthy young males. Eur J Nutr. 2023;62:1295–1308.

75. Lanng SK, Oxfeldt M, Johansen FT, Risikesan J, Hansen M, Bertram HC. Acute changes in the metabolome following resistance exercise combined with intake of different protein sources (cricket, pea, whey). Metabolomics. 2023;19:98.