Dietary Protein

for Female Athletes

GATORADE SPORTS SCIENCE INSTITUTE™

Introduction

Dietary protein is an essential macronutrient which helps the growth of new tissue and the remodeling of skeletal muscle after exercise. Proteins have many different roles in the human body. For athletic performance, protein is commonly associated with muscle and movement. However protein has many other important roles including hormone production, providing structure for cells and tissues, supporting immune system function, moving essential molecules around the body, and enzyme production. Therefore, consuming sufficient protein in the diet is important for all athletes. The information below will discuss the role of protein in the body, how protein supports recovery, and practical advice on how to incorporate protein into an athlete's diet.

The process of building muscle

Human skeletal muscle is constantly being broken down and re-built into new structures, this process is known as protein turnover. When muscle protein synthesis (MPS) is greater than muscle protein breakdown (MPB), the net protein balance is positive, and muscular growth can occur (Figure 1). Amino acids (the units which make up proteins) provided through dietary sources can be used for MPS. Exercise increases both MPS and MPB, therefore muscle protein turnover is high. The exercise-associated adaptations that occur within muscles will depend on the type of exercise performed, as well as the dietary nutrients available.

The figure below shows MPS and MPB in response to three equally sized protein containing meals after either: **(A) no exercise or, (B) resistance exercise.** The shaded areas represent muscle protein accretion, and the non-shaded areas represent muscle protein loss. This demonstrates the importance of consuming protein following exercise to maximize MPS.

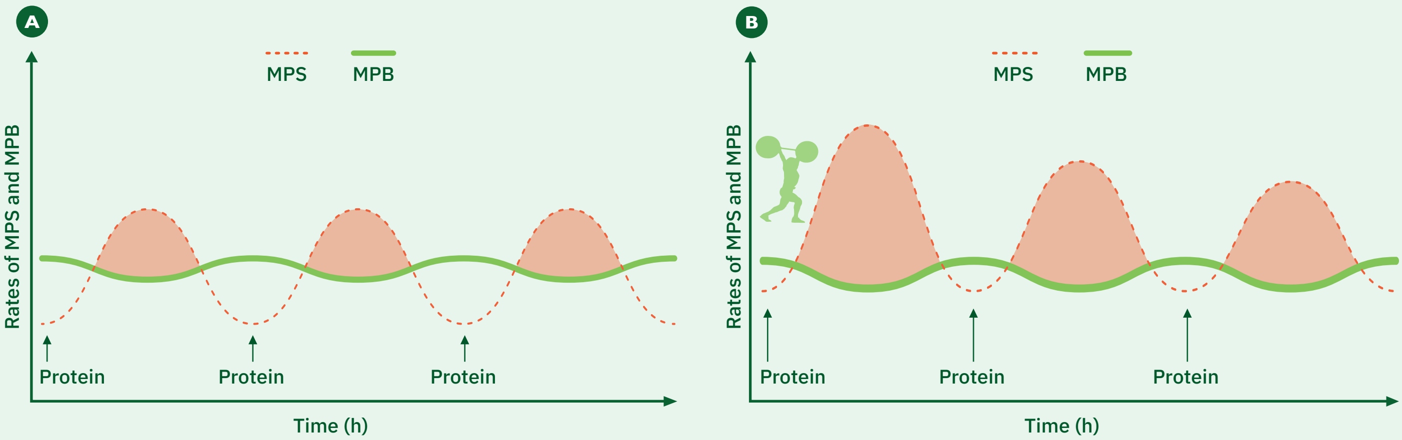


Figure 1: MPS and MPB responses following protein ingestion after either (A) no exercise and (B) resistance exercise

Net protein balance

It is important to ensure that athletes are in either a positive net protein balance, or muscle maintenance, to ensure that they are not losing muscle mass (Figure 2). Athletes can achieve this by regularly consuming adequate amounts of protein in meals and snacks, alongside completing resistance exercise.

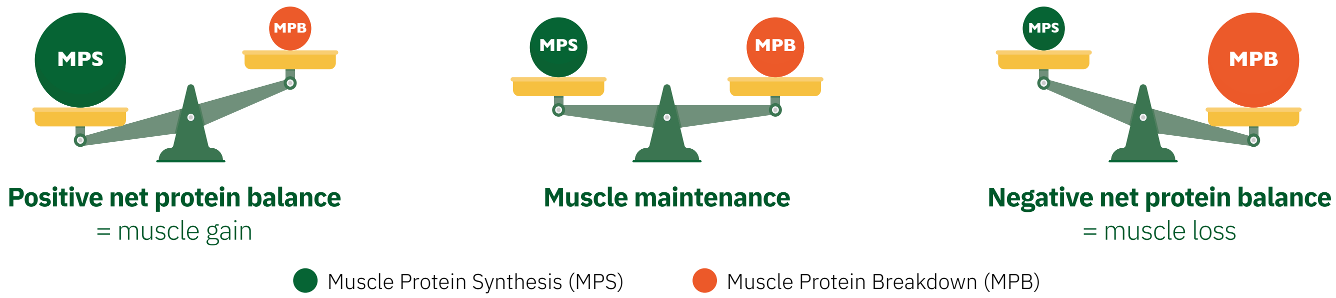
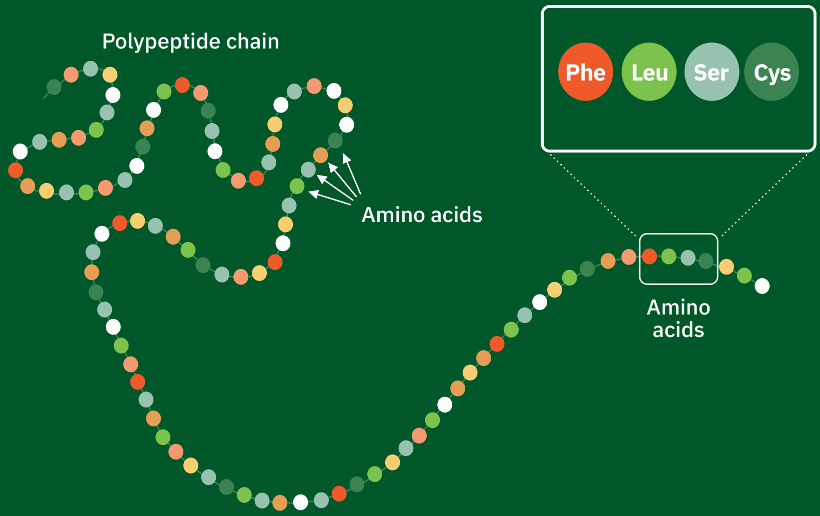


Figure 2: Net protein balance

Dietary protein

Proteins are composed of units called amino acids. There are 20 different types of amino acids, and it is the sequence of these amino acids (also known as a polypeptide chain) that determines the structure and function of a protein.

Amino acids are classified into two groups: essential and non-essential. The body can synthesize (produce) non-essential amino acids, but essential amino acids (EAAs) must be consumed through the diet. Foods which contain all EAAs are considered 'complete' dietary proteins. This is typically animal-based foods such as meat, poultry, fish, eggs, and dairy foods. Plant-based foods (fruits, vegetables, grains, nuts, and seeds) often lack one or more EAA. Combining different plant-based foods that are high in protein is a good strategy for achieving intake of all EAAs within a meal.



Examples of complete dietary proteins

Dairy Poultry Fish Soy Red meat

Essential amino acids	Non-essential amino acids
Not produced by the body	Produced by the body
Important to consume within diet	Not crucial to consume within diet
Histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine	Alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, tyrosine

Dietary protein source and quality

Protein sources contain different amino acid profiles. Both animal-based and plant-based protein sources can play important roles in a balanced diet by contributing a range of amino acids. Creating meals with a mixture of various protein sources, whether from animal- or plant-based sources, helps ensure nutritional needs are met.

Protein quality refers to the nutritional value and bioavailability of the protein. It assesses the ability of a protein to provide EAAs in proportions that meet the body's requirements for growth, maintenance, and repair. Protein quality is measured using a variety of indices, however the most accepted and understood index is the Protein Digestibility Corrected Amino Acid Score (PDCAAS) and the Digestible Indispensable Amino Acid Score (DIAAS). Food sources with high PDCAAS values include eggs, ground beef, whey, casein, milk, and soy.

Factors influencing protein quality

Amino acid profile
High-quality protein sources contain all essential amino acids.

Digestibility
Highly digestible proteins are more efficiently utilized by the body for various physiological functions.

Bioavailability
Refers to the extent to which the body can absorb and use the amino acids from a protein source. Bioavailability can be influenced by factors such as processing methods, food matrix, and antinutritional factors.

Figure 3: Factors influencing protein quality

Common dietary sources of protein

1 medium chicken breast
Serving size: 4.2 oz / 120 g
Protein: 38 g

1 small sirloin steak
Serving size: 3.9 oz / 110 g
Protein: 37 g

Small portion lean ground beef
Serving size: 3.5 oz / 100 g
Protein: 22 g

Half a can of tuna
Serving size: 3.2 oz / 90 g
Protein: 21 g

1 fillet of salmon
Serving size: 3.5 oz / 100 g
Protein: 23 g

1 medium fillet of cod
Serving size: 3.6 oz / 100 g
Protein: 24 g

1 plate prawns
Serving size: 4.2 oz / 120 g
Protein: 21 g

3 medium eggs
Serving size: 6.4 oz / 180 g
Protein: 21 g

1 container cottage cheese
Serving size: 8.8 oz / 250 g
Protein: 23 g

Greek yogurt
Serving size: 7.1 oz / 200 g
Protein: 20 g

1 large glass milk
Serving size: 20.1 fl oz / 568 ml
Protein: 19 g

Skimmed milk powder
Serving size: 2.1 oz / 60 g
Protein: 21 g

1 scoop of whey,
soy or casein protein
Serving size: 1.1 oz / 30 g
Protein: 20–25 g

Tempeh
Serving size: 3.5 oz / 100 g
Protein: 21 g

Seitan
Serving size: 3.5 oz / 100 g
Protein: 24 g

Soy flakes
Serving size: 1.8 oz / 50 g
Protein: 27 g

Large plate quinoa
Serving size: 10.6 oz / 300 g
Protein: 21 g

Mixed nuts
Serving size: 3.2 oz / 90 g
Protein: 20 g

Tofu
Serving size: 3.5 oz / 100 g
Protein: 24 g

4 tablespoons peanut butter
Serving size: 2.1 oz / 60 g
Protein: 19 g

Mycoprotein
Serving size: 7.1 oz / 200 g
Protein: 22 g

1 plate lentils
Serving size: 8.8 oz / 250 g
Protein: 19 g

1 can chickpeas
Serving size: 8.1 oz / 230 g
Protein: 17 g

1 cup edamame beans
Serving size: 7.1 oz / 160 g
Protein: 18 g

1 can baked beans
Serving size: 14.7 oz / 415 g
Protein: 21 g

Daily protein intake recommendations

Female athletes require protein to support adaptation and muscular repair in response to exercise. It is recommended that athletes consume 1.2 – 2.0 grams of protein per kg of body mass per day (g/kg BM/d).

Athletes might require higher protein intakes to:

- Optimize muscle adaptation/recovery during periods of higher frequency/intensity training, or a new training stimulus
- Help maintain muscle mass if sudden or reduced inactivity occurs (e.g., following an injury)
- Prevent increased protein oxidation if carbohydrate intake is low, or if an athlete has low energy availability.

Table 1: Daily protein intake recommendations relative to body mass

Body mass		Recommended protein intake (g) per day based on body mass								
kg	lb	1.2 g/kg BM/d	1.3 g/kg BM/d	1.4 g/kg BM/d	1.5 g/kg BM/d	1.6 g/kg BM/d	1.7 g/kg BM/d	1.8 g/kg BM/d	1.9 g/kg BM/d	2.0 g/kg BM/d
60	132	72	78	84	90	96	102	108	114	120
65	143	78	85	91	98	104	111	117	124	130
70	154	84	91	98	105	112	119	126	133	140
75	165	90	98	105	113	120	128	135	143	150
80	176	96	104	112	120	128	136	144	152	160
85	187	102	111	119	128	136	145	153	162	170
90	198	108	117	126	135	144	153	162	171	180
95	209	114	124	133	143	152	162	171	181	190
100	221	120	130	140	150	160	170	180	190	200
105	232	126	137	147	158	168	179	189	200	210
110	243	132	143	154	165	176	187	198	209	220

g/kg BM/d = grams per kg of body mass per day

Timing of protein intake throughout the day

To maximize adaptations, athletes are advised to evenly distribute their consumption of protein within their meals and snacks throughout the day, in combination with appropriate quantities of other macro- and micronutrients. Consuming a meal or snack which includes ~20-40g protein every 3-4 hours is advisable.

Signifies when protein (~20-40 g) should be consumed

GATORADE SPORTS SCIENCE INSTITUTE ™

Plant-based proteins

Athletes may choose to follow a plant-based diet. The anabolic properties of plant-based proteins are generally lower, likely due to their reduced EAA content when compared to high-quality animal-derived proteins, with many plant-derived proteins being deficient in one or more amino acid(s). In addition, obtaining a sufficient amount of protein from plast-based foods often requires a higher energy intake in comparison to animal-based options (Figure 4). Despite this, with careful planning, athletes following a plant-based diet can consume adequate protein from plant-based foods.

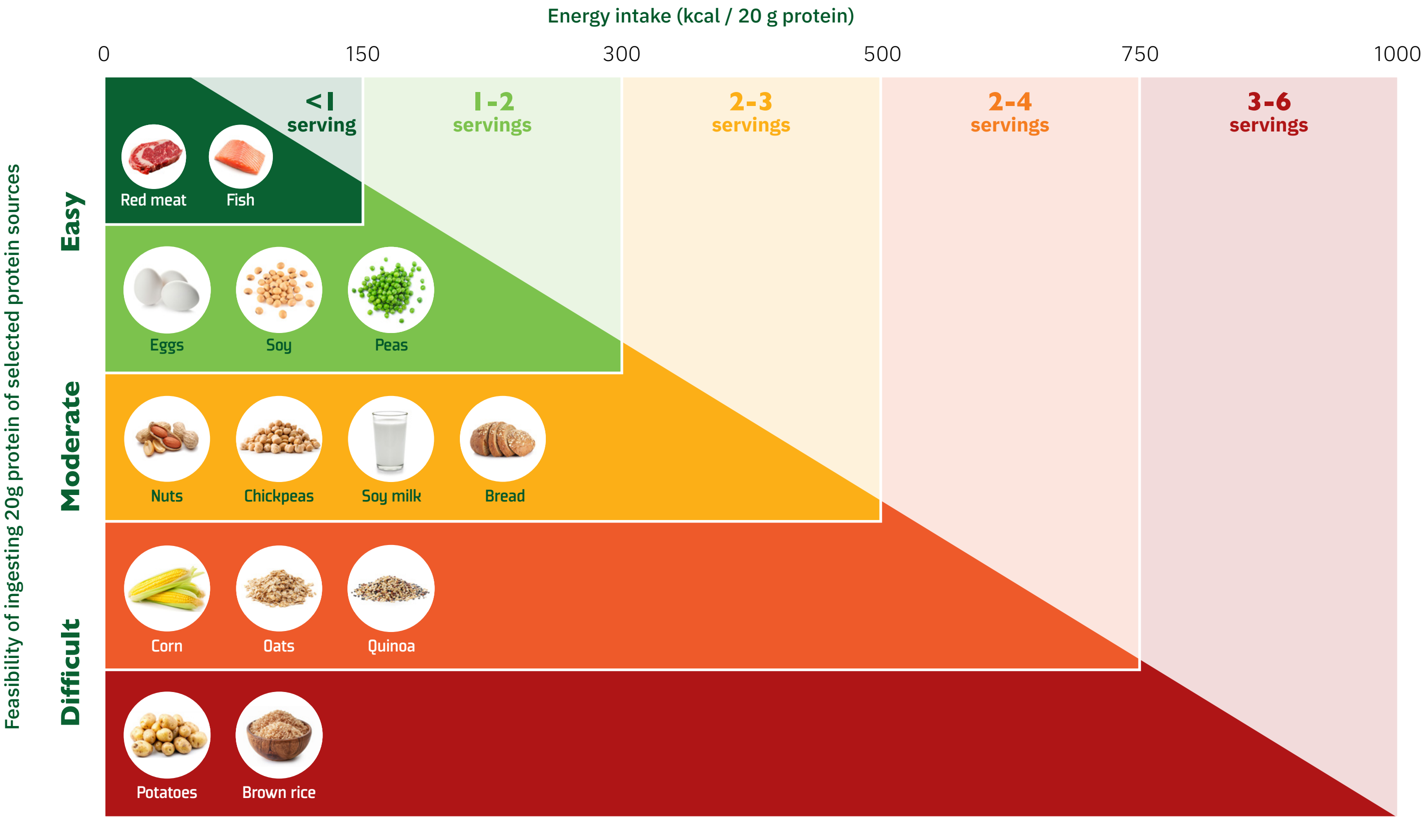


Figure 4: Feasibility to consume 20g protein by consuming whole foods (x-axis) expressed as the number of servings that would be required

Considerations

Those relying on plant-based proteins should ensure they are eating a variety of foods in order to meet their EAA needs, and to support recovery and training adaptations. Combining different plant-based protein sources throughout the day in meals and snacks is a good strategy to ensure that all EAAs are consumed. It should be noted that there are several plant-based foods which are considered complete proteins, and therefore are not lacking in any EAAs (Figure 5).

Plant-based protein, in its natural form, has lower natural digestibility compared to animal-based protein. Processing methods such as heating, soaking, or boiling can improve the digestibility of plant-based proteins. By combining different food groups, increasing portion sizes, and enhancing amino acid availability through processing or cooking, athletes following a plant-based diet can effectively stimulate MPS throughout the day.

Regarding the use of plant-based proteins for recovery and muscle gain, several studies have shown that consuming 30g of protein from plant-based sources (potato or a blend) leads to similar increases in MPS compared to milk protein. Therefore, plant-based proteins are a suitable option post-exercise.

Figure 5: Examples of plant-based foods which are complete proteins

Protein intake around exercise

Exercise causes a slight increase in the oxidation of protein, however protein is not an important energy source during exercise. The energy requirements for exercise are primarily met by carbohydrate and fat. Therefore, protein intake is not a priority immediately prior to, or during exercise. Post-exercise, while there does not appear to be a defined 'window of opportunity', it is important for athletes to incorporate high quality protein into their diet. Consuming protein source(s) which are rich in leucine and contain all EAAs is generally regarded as an effective means to 'turn on' and support maximal rates of MPS immediately after exercise. Ideally, meals/snacks should include ~20-40g of protein, or 0.25-0.30 g/kg BM of protein. When participating in intense whole-body exercise, the protein serving post-exercise should ideally be at the upper end of the recommendation (i.e., 30-40g).

Post-exercise, optimal choices include a balanced meal containing both lean protein and carbohydrates, or any of the snack choices below:

Figure 6: Post-exercise snack options

The importance of leucine

Leucine is an EAA which is important in activating the signaling pathway for MPS. Ingesting a sufficient quantity of leucine (2.5-5.0 g) has been shown to independently stimulate increases in MPS, making the leucine content of dietary protein an important factor to consider. However, it should be noted that leucine does not stimulate a rise in MPS if a full complement of EAA is absent. Therefore, ingesting complete dietary proteins remains important. Foods with a high leucine content include:

Figure 7: Foods with a high leucine content

Protein powders

Protein powders provide a convenient way for athletes to consume additional protein within their diet. Ideally, the majority of an athlete's protein intake should be consumed via whole foods. However, protein powders may be useful when an athlete struggles to meet their daily protein needs through whole foods, or when access to high quality protein is limited e.g., when travelling.

Whey and casein protein (both milk proteins), as well as soy protein, are complete protein sources which have been shown to promote MPS. Soy protein provides a suitable option for athletes following a vegan diet, as well as protein blends which contain a range of plant-based proteins to achieve a full complement of EAA.

WHEY

Whey Protein Isolate

25-30 g serving size suggestion

~2.5 g leucine per serving

SOY

Soy Protein Isolate

25-30 g serving size suggestion

~2.0 g leucine per serving

CASEIN

Casein Protein

25-30 g serving size suggestion

~2.0 g leucine per serving

Sleep

Sleep is often an overlooked occasion for recovery. If protein is ingested prior to sleep, it is digested and absorbed, and used in muscle remodeling. Some pre-sleep protein options include:

Hot cocoa
(made with milk and/or chocolate protein powder)

Bowl of Greek yogurt

Cottage cheese on crackers

Protein shake

Figure 8: Pre-sleep snacks containing protein

Female specific requirements

Research investigating protein requirements specifically for female athletes is limited. However, determining optimal intake within total energy needs is crucial. Female athletes should aim for 0.25-0.30 grams of protein per kilogram of body mass (per serving) to meet their individual needs. Additionally, they should prioritize nutrient-dense protein sources and consider the timing of intake, especially after exercise.

Menstrual cycle

A small number of studies have suggested that there is a small increase in protein utilization at rest and during exercise during the luteal phase of the menstrual cycle.

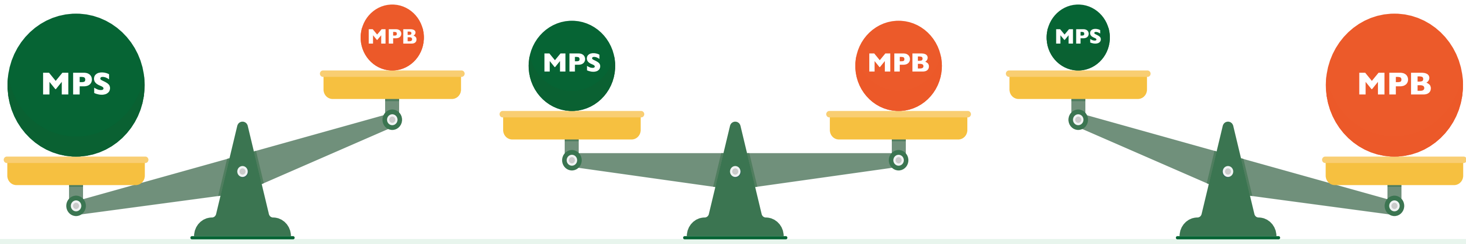
Bone health

Protein plays an important role in optimizing bone health in female athletes (see 'Bone Health' for more information).

Menopause

Protein is a key dietary component during peri-menopause and post-menopause in order to help maintain skeletal muscle mass.

DIETARY PROTEIN



Positive net protein balance
= muscle gain

Muscle maintenance

Negative net protein balance
= muscle loss

● Muscle Protein Synthesis (MPS) ● Muscle Protein Breakdown (MPB)

Daily protein intake recommendations

1.2 g/kg BM/day ↔ **2.0 g/kg BM/day**

Consuming a meal or snack which includes ~20-40g protein every 3-4 hours is advisable

Common dietary sources of protein


Sirloin steak


Canned tuna


Eggs


Mixed nuts


Tofu


Peanut butter


Edamame beans


Chicken breast


Greek yogurt


Protein powder


Chickpeas


Salmon

Female specific requirements

Menstrual cycle

A small number of studies have suggested that there is a small increase in protein utilization at rest and during exercise during the luteal phase of the menstrual cycle.

Bone health

Protein plays an important role in optimizing bone health in female athletes.

Menopause

Protein is a key dietary component during peri-menopause and post-menopause in order to help maintain skeletal muscle mass.

GATORADE SPORTS SCIENCE INSTITUTE™

References and resources

Areta, J. L., Burke, L. M., Ross, M. L., Camera, D. M., West, D. W. D., Broad, E. M., Jeacocke, N. A., Moore, D. R., Stellingwerff, T., Phillips, S. M., Hawley, J. A., & Coffey, V. G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. The Journal of Physiology, 591(9), 2319–2331.

Churchward-Venne, T. A., Pinckaers, P. J. M., Smeets, J. S. J., Peeters, W. M., Zorenc, A. H., Schierbeek, H., Rollo, I., Verdijk, L. B., & van Loon, L. J. C. (2019). Myofibrillar and Mitochondrial Protein Synthesis Rates Do Not Differ in Young Men Following the Ingestion of Carbohydrate with Milk Protein, Whey, or Micellar Casein after Concurrent Resistance- and Endurance-Type Exercise. The Journal of Nutrition, 149(2), 198–209.

Churchward-Venne, T. A., Pinckaers, P. J. M., Smeets, J. S. J., Peeters, W. M., Zorenc, A. H., Schierbeek, H., Rollo, I., Verdijk, L. B., & van Loon, L. J. C. (2019). Myofibrillar and Mitochondrial Protein Synthesis Rates Do Not Differ in Young Men Following the Ingestion of Carbohydrate with Whey, Soy, or Leucine-Enriched Soy Protein after Concurrent Resistance- and Endurance-Type Exercise. The Journal of Nutrition, 149(2), 210–220.

Moore, D. R., Areta, J., Coffey, V. G., Stellingwerff, T., Phillips, S. M., Burke, L. M., Cléroux, M., Godin, J.-P., & Hawley, J. A. (2012). Daytime pattern of post-exercise protein intake affects whole-body protein turnover in resistance-trained males. Nutrition & Metabolism, 9(1), 91.

Phillips, S. M., & Van Loon, L. J. C. (2011). Dietary protein for athletes: From requirements to optimum adaptation. Journal of Sports Sciences, 29 Suppl 1, S29-38.

Phillips, S.M. (2013). Protein consumption and resistance exercise: maximizing anabolic potential. GSSI Sports Science Exchange #107.

Smith-Ryan, A. E., Cabre, H. E., & Moore, S. R. (2022). Functional ingredients to support active women. GSSI Sports Science Exchange #228.

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Medicine and Science in Sports and Exercise, 48(3), 543–568.

Tipton, K. D., & Wolfe, R. R. (2001). Exercise, protein metabolism, and muscle growth. International Journal of Sport Nutrition and Exercise Metabolism, 11(1), 109–132.

Trommelen, J., Kouw, I. W. K., Holwerda, A. M., Snijders, T., Halson, S. L., Rollo, I., Verdijk, L. B., & van Loon, L. J. C. (2018). Presleep dietary protein-derived amino acids are incorporated in myofibrillar protein during postexercise overnight recovery. American Journal of Physiology. Endocrinology and Metabolism, 314(5), E457–E467.

Van Loon, L. J. C. (2013). Is there a need for protein ingestion during exercise? GSSI Sports Science Exchange #109.

https://www.gssiweb.org/en/sports-science-exchange/All/protein