



# Protein for Athletes

## Quantity, Quality, and Timing

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**Protein is the favorite nutrient of athletes because of its ability to stimulate muscle protein synthesis. While the exact amount of protein for muscle growth is not certain it is possible that amounts greater than the recommended dietary allowance of 0.8 g/kg are needed, although the jury is still out. Current guidelines suggest 1.2 to 1.7 g/kg as the amount of protein needed to improve aerobic capacity through mitochondria synthesis and build muscle mass and strength. The timing of protein intake appears to be the most important factor in achieving positive training adaptations. The period immediately after exercise is currently considered the ideal time. High-quality protein sources that contain all of the essential amino acids appear to be the most anabolic. Athletes who consume high-protein diets should also ingest adequate fluids to help prevent dehydration and consume adequate fruits and vegetables to offset any urinary calcium losses that may occur when protein intakes are high. *Nutr Today*. 2009;44(5):204–210**

Protein has long been the favored macronutrient for athletes. The logic is simple: if you want big muscles and muscle is made of protein, then eating more protein equals more muscle. This simple rationale is more fiction than fact, but it is difficult to convince athletes that protein is not the most important nutrient for sports performance. Flip through the pages of any health and fitness magazine, and it is easy to see why athletes worship at the altar of protein—men with bulging muscles who look like cartoon heroes and women with perfectly toned bodies without a drop of cellulite smile from the magazine pages and claim that the latest protein powder, shake, or supplement is all it takes to achieve the perfect body. This review addresses protein quantity, quality, and timing of intake, as well as the myths surrounding the

dangers of excess protein, and discusses the inherent difficulty in assessing how much protein is needed to build muscle and fuel performance.

### Protein Quantity

Skeletal muscle makes up 40% to 45% of body weight and is the largest storage site for amino acids.<sup>1</sup> However, muscle is more than just protein; it also contains water, fat, glycogen, and some minerals. One pound of muscle contains 70 to 105 g of protein, and to build a pound of muscle, it is estimated that 10 to 14 g of additional protein is needed each day,<sup>2</sup> although others dispute this claim. In addition to possible growth of muscle, protein is a highly versatile nutrient and is involved in other functions that are crucial to sports performance: cell regulation, muscle repair, immune function, neurological function, nutrient transport, and structural support.

Ask a sports dietitian how much protein an athlete needs, and the likely answer will be “it depends.” Protein needs are affected by many factors: age, sex, energy intake, carbohydrate intake, exercise type, duration, and intensity, as well as training phase (novice vs trained). Practitioners most often suggest protein in the range of 1.2 to 1.4 g/kg per day for endurance athletes and 1.2 to 1.7 g/kg per day for strength athletes.<sup>3</sup> However, most athletes are very likely to be involved in both endurance and strength activities, so a general range of 1.2 to 1.7 g/kg per day is frequently the shorthand recommendation in practice.

Guidelines for protein quantity were derived from nitrogen balance studies. As Phillips and colleagues<sup>4</sup> pointed out in a 2007 review of protein requirements in athletes, nitrogen balance may be adequate for establishing protein needs to prevent deficiency, but it is likely inadequate to quantify optimal intakes for muscle adaptations needed by endurance or strength-trained athletes. Amino acid oxidation, another technique used in research to determine protein needs during exercise, is also not the perfect measure.<sup>5</sup>

Assessing protein needs for active people is not an easy task. In determining protein needs for sedentary, healthy individuals, the recommended dietary allowance of 0.8 g/kg of body weight relied on nitrogen balance studies.<sup>6</sup> An often forgotten caveat to protein requirements is that 0.8 g/kg is needed when positive energy balance is maintained. Frequently, athletes are not in positive energy balance because of the high caloric requirements for sports training and competition, and for aesthetic sports such as diving and gymnastics, energy is restricted to achieve a thin build. Female athletes are not immune to the social pressures to be thin, and frequently, body image concerns override adequate fueling for sport. At a 2007 Protein Summit, the conference was introduced by reminding the audience that the recommended dietary allowance is not a “requirement of an individual or even a mean for individuals”<sup>7</sup> but is a level of nutrient intake that should be adequate for most individuals. Athletes are not looking for “adequate” intake; they want optimal intake. Athletes frequently make the assumption that “there is a linear relationship between the amount of protein ingested and resulting desirable adaptation of muscle.”<sup>5</sup> The bottom line is that, at present, we cannot pinpoint the exact protein needs of athletes with any degree of certainty.

## Protein Quality

“Whey” better protein, “liquid egg whites,” “soy” good, and even plain old chocolate milk all claim to be the best protein source for athletes. In addition, there are the claims for individual amino acids—glutamine, arginine, and branched-chain amino acids (BCAAs) are all marketed to athletes as giving them special ability to stimulate muscle protein synthesis, provide substrates for fuel, and promote faster recovery. Table 1 summarizes the pros and cons of the various protein supplements.

*Among the relatively complete proteins, which is best?*

## Milk Protein

The dairy industry has long promoted the health benefits of milk but focusing mostly on the micronutrients of calcium, vitamin D, and potassium.<sup>8</sup> To stimulate muscle protein synthesis, weight training or resistance exercise

provides a signal for growth, but without adequate nutrient substrate, maximal growth cannot be achieved. In the mid-1990s, researchers begin to look at the effects of various proteins on absorption and appearance in the blood. Boirie and colleagues<sup>9</sup> studied milk proteins, whey, and casein, to assess how quickly amino acids appeared in the blood after acute feeding of labeled proteins. Whey protein makes up 20% of milk proteins, with casein providing about 80% of protein.<sup>10</sup> Boirie et al<sup>9</sup> showed that whey protein was highly soluble and was a “fast” protein, meaning that after whey protein feeding, the appearance of amino acids in the blood are fast, high, and transient. Casein, a “slow” protein, clots in the stomach, delaying gastric emptying, leading to a slower, lower, but more prolonged appearance in the blood after ingestion.

The dairy industry promoted the advantages of milk protein as unique in containing both fast and slow proteins, which theoretically could provide an advantage for muscle protein synthesis. The theory was simple—whey protein could stimulate protein synthesis but did not appear to affect protein breakdown, whereas the casein in milk could inhibit protein breakdown. It was sort of a “one-two punch” for muscle building simply by drinking a glass of milk.

Several researchers have since shown that milk proteins make for a good muscle building supplement. Wilkinson and colleagues<sup>11</sup> compared milk protein with soy protein on muscle protein accretion. Young, healthy, resistance-trained men consumed isocaloric and isonitrogenous beverages of either soy protein or fluid skim milk after resistance-training leg exercises. The subjects completed 2 trials in random order, and blood flow, amino acid blood levels, and muscle biopsies were analyzed for markers of muscle protein synthesis. Researchers concluded that both the milk and soy proteins resulted in net protein muscle synthesis but that there was a greater rate of muscle mass accrual after milk protein ingestion. The authors believe that milk protein has a unique ability to sustain higher blood levels of amino acids than soy protein, and the prolonged elevation of amino acids in the blood results in a more favorable environment for muscle growth.

A recent abstract<sup>12</sup> supports previous findings about milk protein when used as a recovery beverage in competitive soccer players. Thirteen college soccer players were given either chocolate milk or a carbohydrate energy drink (isocaloric) after intense training and soccer skill tests. The low-fat chocolate milk drinkers had lower levels of creatine kinase—a marker to measure muscle breakdown—than the carbohydrate beverage consumption. However, there was no difference in performance measures in the soccer players when the 2 different beverages were consumed.

**Table 1. Pros and Cons of Various Protein Supplements Commonly Used by Athletes**

Type of Supplement	Pros	Cons
Milk protein	<ul style="list-style-type: none"> <li>Contains both “fast” and “slow” proteins with 80% casein and 20% whey protein</li> <li>Chronic consumption after weight training appears to support lean mass accrual more than other types of protein</li> <li>Inexpensive</li> <li>Taste is familiar to athletes</li> <li>Milk contains carbohydrate and many other nutrients</li> </ul>	<ul style="list-style-type: none"> <li>Whole milk contains saturated fat and cholesterol</li> <li>All milk contains lactose so is not good for lactose-intolerant athletes</li> <li>Requires refrigeration</li> <li>Some athletes complain of “cotton mouth” after drinking milk</li> </ul>
Whey protein	<ul style="list-style-type: none"> <li>“Fast” protein, meaning, that it is rapidly digested, leading to increased amino acids in blood and stimulating protein synthesis</li> <li>May improve immune function</li> <li>May have antioxidant function</li> <li>May decrease cardiovascular disease risk</li> <li>May decrease risk of high blood pressure</li> </ul>	<ul style="list-style-type: none"> <li>Whey protein and whey protein concentrate can contain lactose (whey protein isolate is lactose-free)</li> <li>Expensive</li> <li>Powders have to be mixed with water</li> </ul>
Soy protein	<ul style="list-style-type: none"> <li>Protein quality comparable to animal protein</li> <li>Considered a fast protein</li> <li>Some forms of soy provide isoflavones</li> <li>May reduce prostate cancer risk</li> </ul>	<ul style="list-style-type: none"> <li>May not build muscle as rapidly compared with whey and casein</li> <li>Taste may be unfamiliar to athletes</li> <li>“Bad” press with soy protein (increases breast cancer risk, estrogen-like properties) may influence athletes to avoid soy protein</li> </ul>
Egg protein	<ul style="list-style-type: none"> <li>Considered the “perfect” food because of essential amino acid profile</li> <li>Contains 13 other essential nutrients</li> <li>Egg whites are fat-free, cholesterol-free</li> </ul>	<ul style="list-style-type: none"> <li>Egg yolk is high in cholesterol, and half of the protein in egg is found in yolk</li> <li>Raw eggs can be a source of <i>Salmonella</i></li> <li>Some athletes may be allergic to eggs</li> </ul>
Amino acids	<ul style="list-style-type: none"> <li>Theoretically could provide specific substrate for specific functions                             <ul style="list-style-type: none"> <li>• Arginine produces nitric oxide needed for blood vessel dilation</li> <li>• Glutamine for immune function</li> <li>• Branched-chain amino acids as fuel source in endurance events</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Lack of research supporting ingestion of amino acids on performance</li> <li>Tastes bad</li> <li>Expensive</li> </ul>

## Whey Protein

Whey protein is one of the most popular (and most advertised) protein supplements to athletes. Does whey protein have an advantage over milk protein’s whey and casein? Tang and colleagues<sup>13</sup> wanted to know if whey protein did indeed live up to its hype by studying the effect in the postexercise period in resistance-trained subjects. This is an important distinction because many studies with protein supplementation are conducted with untrained subjects—in studies that enrolled untrained subjects, the results of supplementation are almost

universally positive, but can the same be said when individuals are already accustomed to weight training? In a double-blind, randomized, crossover trial involving leg extension to maximal resistance, young resistance-trained men were given 1 of 2 isocaloric beverages—carbohydrate-only or whey protein plus carbohydrate. Results, based on tracer injections, showed that whey protein plus carbohydrate induced greater muscle protein synthesis compared with the carbohydrate trial. In this study of strength-trained men, whey protein supported positive net protein balance that created a favorable environment for muscle hypertrophy.

It is also important to note that the amount of protein needed to stimulate muscle growth is not large—more is not necessarily better when it comes to muscle growth—10 g of whey protein plus about 20 g of carbohydrate was sufficient to build muscle.

What is so special about whey protein compared with other protein supplements? Researchers believe that the key could be the amino acid leucine, one of the BCAAs. Whey protein has the highest amount of BCAAs of any protein. After exercise, leucine stimulates signaling pathways to stimulate muscle protein synthesis.<sup>14</sup> Norton and Layman<sup>15</sup> reported that leucine serves as a crucial regulator of protein synthesis and is donor of nitrogen to alanine and glutamine, 2 important amino acids in muscle protein synthesis. Researchers are excited about this “leucine trigger,” as it may have important implications not only for muscle growth for healthy athletes but also for prevention and treatment of sarcopenia or age-related loss of muscle and function in older adults.<sup>16</sup>

## Egg Protein

Egg has often been called the “perfect protein” because of its amino acid profile and has been used as the standard for comparing other dietary proteins. Eggs are also rated high on digestibility, so combined with its amino acid content, it is an excellent source of protein for athletes.<sup>17</sup> (For a detailed review of egg nutrition, see Layman and Rodriguez<sup>17</sup>). Eggs are a familiar food to athletes, but maybe, that familiarity makes them seem mundane, especially when other dietary supplements have more aggressive marketing campaigns. Eggs also have the bad reputation of being an unhealthy heart food based on cholesterol concentrations. One large egg has 75 cal, 6 g of protein, and 213 mg of cholesterol, but only 1.5 g of saturated fat; however, the egg white provides all of the amino acid benefits without the cholesterol. One large egg white has 16 cal with 3.5 g of protein and is fat-free. Research using eggs as the protein source for muscle growth is lacking, perhaps because of less available research funding from the egg producers when compared with the money from the dairy industry. However, egg protein is clearly a high-quality source of protein, but it takes 4 or 5 eggs to get the 10 g of essential amino acids that appear to be needed for stimulating protein synthesis.<sup>4</sup>

## Soy Protein

Soy protein is a high-quality protein that provides all of the essential amino acids needed for protein synthesis.<sup>18</sup> Soy protein can be used by vegetarian athletes as a good alternative to meat and dairy foods to meet their protein needs. Soy protein powder is also

available as a muscle-building supplement. Candow and colleagues<sup>19</sup> studied soy protein (1.2 g/kg of body weight) on untrained young adults and compared it with whey protein (also at 1.2 g/kg) and found that both soy and whey protein increased lean mass compared with placebo. Other researchers<sup>20</sup> have shown that whey protein is superior to soy protein for muscle anabolism, but the results should not be interpreted that soy protein has no effect on muscle growth. However, Candow et al used untrained subjects, and one would expect that muscle gains are greater in untrained subject versus trained subject whether ingesting soy or whey protein.

## Protein Timing

One of the most important aspects of protein intake and muscle protein synthesis revolves around the timing of protein intake relative to exercise. Exercise, whether resistance or endurance activity, requires protein to aid in the adaptations that the athlete seeks. Weight lifters want an increase in size and strength of muscle fibers, and endurance athletes want more and bigger mitochondria to improve oxidative capacity.<sup>5</sup> Resistance exercise leads to muscle trauma. Nosaka<sup>21</sup> notes that muscle damage can be classified as 3 different types: muscle soreness, occurring 24 to 48 hours after exercise and often called delayed onset muscle soreness; acute damage from a minor to a major tear in muscle fibers; and muscle soreness or a cramp that happens during or immediately after exercise. The amount of muscle damage that athletes sustain in training may not be severe, but muscle damage does occur during and after exercise, so recovery is an important aspect of athletic training.

Most of the research on protein timing focuses on the postexercise period. Most researchers would agree that protein ingestion, either as food, supplements, or amino acids, in the period immediately after exercise (usually defined as within 1 hour) is an effective nutrition plan to minimize protein breakdown, stimulate muscle protein synthesis, and therefore aid in building muscle.<sup>4,22</sup>

*Does timing of protein intake  
make a difference?*

Humi and colleagues<sup>23</sup> looked at timing of protein intake both before and after resistance training in young men. They measured muscle area using magnetic

resonance imaging and performed muscle biopsies before and after 21 weeks of weight training and a control period. Using 15 g of whey protein given both before and after training, they found increased muscle area in all supplementation phases, but more of benefit (as measured by markers of protein breakdown) when protein was ingested after exercise. They concluded that protein intake timed around resistance exercise is more advantageous than protein intake at other times of the day.

However, Humi et al<sup>23</sup> used untrained men in his study. Hoffman et al<sup>24</sup> studied 10 weeks of protein supplementation on about 30 resistance-trained men. In this study, a higher dose of commercial protein supplement was used than in other studies (42 g of a blend of collagen, whey, and casein along with 2 g of carbohydrate) and was compared with a control group with no supplementation. Outcome measures included body composition analysis (dual-energy x-ray absorptiometry) and strength exercises performed to 1 repetition maximum. After 10 weeks, no differences between groups, suggesting that those individuals who are resistance trained will gain no further benefits from ingesting additional protein either before or after exercise.

### Excess Protein and Health

One concern that always comes up when talking about excess protein are potential health risks. Will excess protein harm the kidneys or leech calcium from bones leading to an increase in fracture risk? While research on high protein consumption and specific athlete populations is limited, a few studies have shown that high-protein intakes do not have adverse effects on renal function as measured by glomerular filtration or creatinine clearance in healthy body builders.<sup>25,26</sup> Both studies were conducted in Europe, and it would be helpful to have additional research in a US athlete population to assess the impact of a high-protein diet on renal function.<sup>27</sup>

*Can we get too much of a good thing like protein?*

Bone volume is made up of about 50% protein and about one-third of its mass.<sup>28</sup> Early studies showed that, for every gram of excess protein consumed, there is a 1-mg loss of urinary calcium. Heaney and Layman<sup>28</sup> note

that the frequently cited study was done using purified amino acid injections—not food sources of protein. With high-protein diets, up to 30% of energy as protein, there is a slight increase in urinary calcium excretion, but there is also an increase in intestinal calcium absorption. Protein consumption (in the range of 1.0–1.5 g/kg) is associated with an increase in insulinlike growth factor 1, which is osteotrophic. One concern with high-protein intake on bone health is the effect on acid-base balance. A high protein, “Western”-type diet is acid forming and is associated with calcium loss in the urine. Calcium gets recruited from bone to buffer the acid and over time can contribute to bone loss. To negate this negative impact, adding fruits and vegetables to the diet can be an effective strategy.<sup>28</sup>

Overlooked in the discussion of high intake of dietary protein are its effect on hydration and the potential to displace carbohydrate. At intakes greater than 2.5 g/kg, urea production from deamination can contribute to dehydration.<sup>29</sup> Urea is osmotically active and draws water into the kidney tubules, increasing urine output and decreasing total body water. Carbohydrate, critical for aerobic and endurance exercise, is also important in strength training. Muscle glycogen reduction is seen after weight training, and in weight-lifting sessions that last an hour or longer, carbohydrate ingestion improves performance.<sup>4</sup> All athletes should balance protein intake with sufficient carbohydrate intake and adequate fluids for peak performance, as well as long-term health.

### What Is the Future of Protein Research?

There is still much to be learned about protein and sports performance. What is the best outcome measure? What is the most appropriate assessment tool? What is the ideal timing for protein intake? Are dietary proteins or single amino acid preferred by muscle for anabolic stimulation? How do researchers control for diet and lifestyle factors in a free-living population when studying protein and muscle hypertrophy? Another line of research that is gaining interest is the marriage of other muscle-building supplements with protein; both whey protein and creatine monohydrate with and without conjugated linoleic acid have been studied to see if it is a superior combination.<sup>30,31</sup> Right now, the jury is still out, but we can expect to see more research with multiple substrates in hopes of finding the ideal supplement to build muscle.

### Conclusions

We know that athletes believe in protein pills, powders, and shakes, even though food sources might be just as

effective as expensive supplements. Duellman et al<sup>32</sup> found that high school athletes still have a lot of misconceptions about the effectiveness of protein supplements, and even military recruits report protein as the most commonly used supplement to build muscle.<sup>33</sup> Even though researchers have shown dietary protein in milk to be a good, if not superior, protein source compared with other protein supplements, athletes believe in supplements and certainly prefer their convenience and ease of use.

## Practice Guidelines

- Protein intake in the range of 1.2 to 1.7 g/kg is sufficient to build muscle when energy intake is sufficient.
- The acceptable macronutrient distribution range has an upper limit of 35% protein of total energy and serves as a good guide for protein intake.
- Time protein intake to coincide as closely as possible to exercise; current research suggests that after exercise is the ideal time to consume protein.
- High-quality protein sources are preferred for muscle growth (eggs, dairy, and lean meat protein).
- High-quality protein in amounts of 10 to 20 g appears to be the maximal amount needed, and more is not better.

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### Common Food Dye May Hold Promise in Treating Spinal Cord Injury

A common food additive that gives M&Ms and Gatorade their blue tint may offer promise for preventing the additional “and serious” secondary damage that immediately follows a traumatic injury to the spinal cord. The researchers report that the compound Brilliant Blue G (BBG) stops the cascade of molecular events that cause secondary damage to the spinal cord in the hours following a spinal cord injury, an injury known to expand the injured area in the spinal cord and permanently worsen the paralysis for patients.

In a fluke, researchers discovered that BBG, a known P2X7R antagonist, is both structurally and functionally equivalent to the commonly used FD&C blue dye no. 1. Approved by the Food and Drug Administration

as a food additive in 1982, more than 1 million pounds of this dye are consumed yearly in the United States; each day, the average American ingests 16 mg of FD&C blue dye no. 1. An intravenous injection of BBG proved to significantly reduce secondary injury in spinal cord-injured rats, who improved to the point of being able to walk, although with a limp. Rats that had not received the BBG solution never regained the ability to walk. There was 1 side effect: rats who were injected with BBG temporarily had a blue tinge to their skin.

Further laboratory testing will be needed to test the safety of BBG and related agents before human clinical trials could begin. Nonetheless, the investigators are optimistic that, with sufficient study, strategies like this could yield new treatments for acute spinal cord injuries within the next several years.

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