Dietary Protein and Strength Athletes
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SUMMARY
DIETARY PROTEIN, PARTICULARLY IN THE AMPLE AMOUNTS USED BY MANY STRENGTH ATHLETES, HAS LONG BEEN CONTROVERSIAL, IN PART BECAUSE OF LACK OF DATA. THE SAFETY (E.G. RENAL AND BONE HEALTH) AND EFFICACY (ENHANCED PROTEIN SYNTHESIS, MUSCLE ACCRETION, AND FAT LOSS) OF VARIOUS PROTEINS HAVE NOW BEEN RESEARCHED TO VARYING DEGREES, HOWEVER. PROTEIN TYPE, DOSE, PERI-EXERCISE TIMING, ENERGY INTAKE, AND TRAINING STATUS ARE CONSIDERATIONS. RECOMMENDATIONS SHOULD NOT BE EXTRAPOLATED FROM OTHER POPULATIONS. THIS REVIEW COVERS DATA SPECIFIC TO THE STRENGTH TRAINING POPULATION AND OFFERS PRACTICAL ADVICE ON MANIPULATING PROTEIN FOR OPTIMAL BENEFITS.

INTRODUCTION
Assessment of best practices in sports nutrition typically involves some form of safety and efficacy evaluation from the scientific literature. With regards to dietary protein, practical translation from published findings has been difficult at times. Meaningful data have not been available on key issues, which have led to controversy. Different professions seem to have adopted different views. Clinicians and health educators share messages that are not always in agreement with exercise and nutrition scientists on topics such as the safety of large intakes (27,30,31). Unfortunately, data from nonathletic populations and unsubstantiated professional opinion have often been used in educational materials (30). Indeed, textbooks sometimes reference each other rather than using relevant primary literature and thus have perpetuated certain health concerns. Recent strength athlete–specific data do exist, however.

The efficacy of dietary protein for building and repairing various tissues, providing building blocks for bodily enzymes, immune proteins, and transporters and for helping to maintain bodily fluid balance and pH clearly makes it an essential nutrient. Indeed, there have been suggestions from scientists to increase “official” governmental recommendations in coming years (15,23). Decades of research exist supporting protein’s role in enhanced muscle protein synthesis, both when considered as daily intake and when timed close to resistance exercise (3,34,39,41,42,51,53). Despite this consensus that acute protein synthesis is increased with purposeful, well-timed intake, it is less clear scientifically how much muscle accretion is augmented over time. This is, in part, due to wide variation in individual responses to the resistance training stimulus. Although enhanced muscle gains are probable, the hypertrophy would come slowly (43,48,50). Certainly, protein intake is not infinitely linear in its relationship to nitrogen retention or protein synthesis, even for strength athletes. At some point as dosing escalates, nitrogen excretion becomes substantial (indicating waste, in a sense). Physiologic limits of anabolic hormones, for example, determine how far the dietary protein and resistance exercise stimuli take the athlete. Ample protein intake beyond nitrogen equilibrium does not necessarily lack value; however, it may offer advantages such as affecting intracellular signaling pathways or offering satiety or increasing metabolic rate. Finally, variables such as protein type, dose, peri-exercise timing, energy intake, and training status all affect outcomes in research and thus affect sports nutrition recommendations for athletes.

PROTEIN SAFETY (LARGE INTAKES)
It is interesting to note that safety data specific to healthy persons or certainly to strength athletes consuming ample protein is quite limited. Scientific examinations of issues commonly mentioned by clinicians, such as renal “stress,” dehydration, gout, bone catabolism, and an adverse impact on diet quality (e.g., fiber or saturated fat intake), have been few. Pencharz et al. (40) concluded: “the data on the safe upper limits of amino acid intake in humans is essentially observational.” These researchers suggest that an experimental “rational basis” is needed to define the upper limits of tolerance for dietary amino acids. We should not rely on extrapolation or professional opinion, perhaps even less so from nonscientists and nonathletes.

KEY WORDS:
protein; protein synthesis; whey; casein; soy; milk; beef; egg; postworkout; timing; nutrition; hypertrophy; energy; kcal; supplement; whole food
Indirect research and plausibility arguments that generate concern, such as the “Brenner hypothesis” (increased kidney filtration is damaging), have not been borne out in limited population-specific studies. For example, 2 early investigations by Poortmans and Dellalieux (44) and Brändle et al. (7) found no adverse effects of high-protein diets—although both studies compared large male strength athletes with somewhat dissimilar control groups (27,30). New research by Lowery et al. (28) more closely addressed certain control issues and reported no differences in kidney “damage” (urinary microalbumin) or kidney function (creatinine clearance) in quasi-experimental designs of strength athletes consuming very large amounts of protein (approximately 250 g daily; 3.2 g/kg body mass; 34% of energy intake) compared with controls on a more typical diet. Importantly, these designs involved long-term data, using self-reported intakes of over a decade (28).

Protein-focused research on bone resorption and ultimately bone mineral density (BMD) is similarly uncommon, with specific data on strength athletes only becoming available in 2009–11 to our knowledge. Older data on the calcium of high-protein (e.g., meat) diets in nonlifters suggested potentially deleterious effects (17). Concerns and cautionary language on bone loss, based on these findings, are still present in educational materials offered to college students and by certain personal training groups (30). This has, however, drawn critique from the scientific community because extra calcium in the urine does not equate to low BMD or increased fracture risk (14,36). Indeed, Lowery et al. (32,33) reported no differences, after correcting for body mass differences, in whole-body or site-specific BMD when comparing strength athletes who do or do not habitually seek extra protein in the diet.

Similarly, data on purported dehydration, gout, and poorer diet “quality” have not been supported by scientific study in strength athletes (27,28,29). This is not to say all sports that involve resistance training will have similarly benign findings or that very long durations of intake beyond a decade are completely without consequence. These are topics for future research. The current, practical conclusion that can be made by a review of the literature is that large protein intakes in healthy strength athletes, such as weightlifters, bodybuilders, powerlifters, and strongman athletes can be wasteful but do not appear harmful—up to perhaps 3 g/kg daily and over periods of about 10 years.

PROTEIN TYPES

The concept of dietary variety is a widely accepted one, ensuring that the individual receives a broad spectrum of nutrients, does not overconsume any one nutrient or contaminant, and of course complies with his training diet. This section thus explores a variety of protein food options. There are 5 primary types of dietary protein that will be discussed: whey, casein, soy, egg, and beef. These protein types can be found in a variety of dietary sources. Whey and casein are milk proteins. Milk proteins combined with resistance training have been linked to an increase in protein synthesis and an increase in muscle strength (16,20,26,50). Egg protein supplements are derived from chicken egg whites or whole egg sources. There are limited studies linking the effects of egg protein in response to athletes (24,37,39). Soy protein is found in the soybean and is generally considered a complete protein. This nonanimal protein is thus a widely accepted vegetable protein source. Soy can be used by athletes searching for nonanimal proteins or by those with lactose intolerance. Beef is also a high-quality complete protein—one that also contains zoochemicals, such as creatine and carnosine, that may be beneficial to strength athletes. These 5 proteins come in various forms and have different physiologic effects.

The milk protein whey is a derivative of a curd processing technique of milk. Whey is divided into a few supplemental forms: isolates, concentrates, and hydrolysates. The differences of these forms are in the processing method. Isolated whey proteins, or simply concentrated forms (less pure in a sense), are very high-quality proteins but whey hydrolysates (enzymatically predigested in part) are also available. Again, note that whey isolates are considered more specific to the protein itself, as opposed to whey concentrates that include greater amounts of other substances. As noted by Campbell (10), “The primary differences among these forms are the method of processing, plus small differences in fat and lactose content, and amino acid profiles. Whey protein isolate is the most pure and concentrated form of whey protein available. It contains 90% or more protein and very little fat and lactose. Whey protein concentrate has anywhere between 25% and 89% protein depending upon the product.” Whey hydrolysate supplementation—arguably the optimal form of whey—has been shown to increase muscle protein synthesis greater than soy and casein postresistance training (49). Furthermore, studies have found that hydrolyzed whey isolate can increase actual gains in lean mass and strength over 10 weeks compared with casein (13). It is logical, especially considering further studies on acute protein synthesis and training gains performed by Phillips et al. (42,43) that whey proteins, including isolates and hydrolysates, are the best choice for muscular gains when consumed postworkout. These facts, along with whey’s superior solubility to traditional casein, make it attractive.

But what of other complete proteins? Casein, the main protein in common cow’s milk, is referred to as a “slow-digesting protein” (41) compared with whey, egg, and soy because it clots in the stomach. In a number of studies, casein did not increase protein synthesis like whey protein postexercise (4,49,53). However, casein prevents bodily protein breakdown by promoting an antinutritional effect that is not found in whey protein (4). Casein may also be superior for satiety (1). Although it may not be the single best choice from a protein synthetic perspective, casein can be an inexpensive...
high-quality protein choice. Indeed, data does exist, suggesting it may be similar in efficacy to whey in the long run. As stated by Tipton et al. (53) and restated by Phillips et al. (43), "Both whey and casein protein have recently been demonstrated to be effective in supporting a positive leucine and phenylalanine balance following resistance exercise, with no apparent difference between the two proteins." From a whole-body perspective, the lingering elevation in amino acids seen after casein ingestion suggests that it may be beneficial to consume in the evening, before the overnight fast. This is speculation, however, given the notion of refractoriness (serum amino acids do not indefinitely increase muscle protein synthesis). This is not to say casein is the only, or even the single best, choice in the evening. To the authors’ knowledge, evening protein comparisons have not been reported. An athlete’s goals and needs can help determine protein choices. For example, whey may enhance sleep quality or next day alertness (35). Yet in the interest of dietary variety, food preferences, protein quality, functional food properties, and whole-body protein synthesis, casein is a valid choice.

Soy protein foods, like whey, have 3 subcategories: soy flour, soy concentrate, and soy isolate. Soy isolate has the greatest concentration of protein compared with concentrates and flour (22). Soy protein can be an inexpensive adequate option for supplementation. Much of the lay concern regarding soy’s estrogenic or feminizing effects among strength athletes appears overstated. Nevertheless, some hormonal concerns are indeed present in the scientific literature, and soy does have a poorer leucine content than whey (47). Despite its similar protein quality (protein digestibility–corrected amino acid score, PDCAAS) and relative speed of digestion/absorption, soy does not increase muscle protein synthesis as much as whey protein does (49). For these reasons, soy is best suited for those eschewing high-quality animal products, such as whey or egg. Soy is probably not the preferred protein choice for omnivores, given the lactose free availability of physiologically superior and more neutral tasting, versatile dairy proteins (Table 1).

Egg protein probably gets less attention than whey, casein, or soy but is a recommended, very high-quality protein. Egg protein is widely known among nutritionists to be ranked highly in various measures of protein quality (protein efficiency ratio, PDCAAS, etc.), and eggs offer functional food benefits and nutrients not found to the same extent in dairy proteins or meats (2). Indeed, it was egg protein that was investigated by Moore et al. (39) when they determined that a 20-g post-workout dose was close to the optimal dose for peak protein synthesis. Eggs may best be consumed as whole foods because of their nutrient richness, functional food qualities, and quick preparation.

Dietary sources of beef protein include hamburger, beef tips, cubed steak, and other cuts of meat derived from cows. Because of its solid nature, beef protein is a slower-digesting protein. The value of beef to resistance trainers is established, but studies differ somewhat with regards to its superiority versus a lacto-ovo vegetarian type of diet, at least in older men (11,21). Beef is a rich source of calories and nutrients, such as creatine, that may support muscle gains. Early research by Ingwall (25), using cultured cells and organs, suggested that creatine was the chemical signal coupling increased muscular activity with contractile mass. However, Haub et al. (21) performed a study focused on the effectiveness of a lacto-ovo vegetarian type of diet versus a beef-based diet and found no significant differences in strength, body composition, resting energy expenditure, and muscle creatine/phosphocreatine. Beef’s primary advantage may be in its

<table>
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<th>Table 1</th>
<th>Protein characteristics and practical applications</th>
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<td><strong>Proteins</strong></td>
<td><strong>Speed of protein</strong></td>
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<tr>
<td>Whey</td>
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<td>Casein</td>
<td>Slow</td>
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<td>Soy</td>
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<td>Egg</td>
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<td>Beef (meat)</td>
<td>Slow (solid)</td>
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*Speculation based on satiety and/or daily preferences and/or whole-body protein retention.
culinary versatility and attractiveness to many strength trainers.

**PROTEIN TIMING AND DOSE**

The timing of ingested protein in relation to a bout of resistance exercise is perhaps the most promulgated aspect of sports nutrition because the post-exercise "carbohydrate window" concept was popularized in the 1980s and 1990s. Earlier protein synthesis work by researchers, such as Tarnopolsky, has been continually expanded upon by these investigators and their colleagues such as Tipton and Phillips. Importantly, these researchers and others have shown that the stimulus of resistance exercise opens a muscle protein synthetic "window of opportunity" that is additive or synergistic with the provision of other stimulatory factors, such as the amino acid leucine (of which whey protein is richest), insulin release from eating, and amino acid building blocks in general. The net effect between the immediate post-exercise period and perhaps 36 hours later appears to be greater activation of the mammalian target of rapamycin pathway within muscle cells, positively affecting protein synthesis (34).

As discussed in the “Protein Types” section of this article, whey protein may be the ideal source of rapidly accessible amino acids to pair with the resistance exercise stimulus (42,43). Indeed, a recent quote from Phillips’ group is summarative: “There is mounting evidence that the timing of ingestion and the protein source during recovery independently regulate the protein synthetic response and influence the extent of muscle hypertrophy” (8).

The optimal single dose of peri-workout protein appears to be 10–20 g, although different types of protein may differ to some extent (39,45,48,54). Earlier data (48,54) suggest that approximately 6–40 g of protein (and/or indispensable amino acids) is effective at increasing protein synthesis post-workout. In the context of an entire day, this is not a large amount (a few eggs or 1–2 scoops of protein powder), and resistance trainers routinely consume double this amount in peri-exercise drinks and meals. It is interesting to note that an optimal leucine dose is contained in a typical serving of whey protein (the richest source of this stimulatory amino acid). With consideration for metabolic effects beyond protein synthesis, from satiety to a high thernic effect to potential for psychological and immune support during hard training, substantial daily protein intakes approximating the traditional “one gram per pound” are not unreasonable for healthy athletes (31,52).

**ENERGY INTAKE AND TRAINING STATUS**

Daily energy intake affects protein needs. As stated by Butterfield (9): “…when energy balance is negative, an intake of protein as high as 2 g x kg body weight x d^-1 may be inadequate to maintain N equilibrium.” That is, on a low calorie intake, even fairly large amounts of protein may not be enough. Butterfield (9) also demonstrated that as one adds more and more daily kilocalories above his requirement, he tends to experience better and better nitrogen retention. This is not a new concept. Data from Chiang and Huang (12) illustrated that for each 15% increase in kilocalories intake, nitrogen retention progressively increased. Specifically, at a fixed protein intake of 1.2 g/kg daily, there were incremental increases in nitrogen retention with greater kilocalories consumption. At maintenance energy intake, 15% above maintenance energy and at 30% above, nitrogen balance increased from 7.2 to 23.8 to 33.3 mg N x kg^-1 x d^-1 in the “ascending calorie series and decreased from 27.8 to 17.6 to 4.8 mg N x kg^-1 x d^-1 in the descending series. These classic data are corroborated by overfeeding studies by Roberts et al. (46) and Bouchard and Tremblay (6), in which nonlifters exhibited a body protein deposition of 13–33% of 1,000 kcal daily surpluses. Note that these are nonathletes. Although energy surplus alone is not sufficient for optimized muscle protein synthesis, this is a practical point of which coaches and athletes should stay cognizant. Many athletes undereat or skip meals (31), a fact that would hamper muscular gains.

Focusing too much on protein is not optimal, as illustrated by some of the math involved. With approximately 2,800 surplus kcal (and just 72 g of protein) necessary to build a pound of new muscle tissue (6,18,55), regular meals should always be addressed when working with athletes. A typical college male needs approximately 3,000 kcal per day (5), so it is not unheard of for a collegiate athlete to need upward of 4,500 kcal daily—not easily done with healthful dietary variety, given daily schedules and demands. In fact, protein’s high satiety value could interfere with athletes’ attempts to gain weight. It is suggested that, when an athlete asks whether s/he should seek extra protein, a coach replies with his or her own question: “That depends; how many calories are you consuming?” More specifically, athletes differ nutritionally and in their training, so a coach should consider the overall diet when screening the need for seeking extra protein. If an athlete is not skipping meals and consumes multiple servings of foods—including complete proteins of animal origin—then each of 4 or more meals and snacks, just one or perhaps 2 scoops (approximately 20–40 g) of whey protein post-workout is likely enough.

Training status also appears to play a role. Research by Hartman et al. (19) suggested that dietary requirements for protein in novice resistance-trained athletes are not higher, but lower, after 12 weeks of resistance training. It is interesting that more experienced lifters (those who are adapted to resistance training) may actually need less protein, provided energy is adequate. This is not to say that ample protein intake is unimportant for this population. Although data by Hartman et al. (19) suggest well-adapted lifters, consuming plenty of calories may have lower protein requirements; official protein needs (i.e., the recommended dietary allowance) do not technically differ between novice and advanced resistance trainers. Further, seeking ample protein intake at any
state of training has a favorable benefit-to-risk ratio. Physique gains and other health benefits (31) appear probable without risks for healthy persons. (Again note: One should stay cognizant that energy intake is often inadequate in hard training athletes and should be screened.)

But what of other potential benefits, other than nitrogen retention, during novice through advanced training? “Functional food” proteins, such as whey, may play a role in such things as antioxidant defenses, body fat control, and reduced overtraining risks (31,38). More research is needed in these areas.

**SUMMARY**

Dietary protein interventions are a safe and effective tool for strength athletes in their pursuit of muscular gains and potentially enhanced performance over time. Although strength athletes often overconsume protein, perhaps in response to marketing by the food and supplement industry, the now common practice of consuming perhaps 20 g of (usually dairy) proteins after resistance exercise is recommended.

From a practical perspective, the principle of dietary variety should be applied. Protein-rich foods are more than just vehicles for specific proteins or amino acids, and protein is a nutrient that is essential for reasons beyond just muscle mass. Protein foods offer a variety of nutrients and benefits to the hard training strength athlete. Dairy foods and/or supplements offer whey, casein, minerals (notably calcium and potassium), and hard-to-get vitamins like vitamin D. Eggs are rich sources of carotenoids like lutein and zeaxanthin, as well as choline (2). Soy foods may contain fiber and provide an adequate protein source for vegans. Meats contain zoochemicals and readily absorbable iron that dairy products do not contain. Individuals also have different taste preferences. Further, the various proteins exhibit different physical properties that are useful in preparing certain recipes. Finally, portability of proteins without spoilage (i.e., dry meats and powders) is also of practical benefit during busy schedules (Table 2).

**REFERENCES**


| Table 2
Supplemental and whole-food protein pros and cons: practical applications |
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<td><strong>Pros</strong></td>
<td><strong>Cons</strong></td>
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<td>Supplemental proteins</td>
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<td>Fast preparation</td>
<td>Easy to overdose/overconcentrate (gastrointestinal osmotic distress)</td>
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<td>Low spoilage risk (dry powders, bars)</td>
<td>Cost of specialty formulas</td>
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<td>Quickly corrects inadequate intakes</td>
<td>Liquids are less-filling (pro or con)*</td>
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<td>Liquids facilitate surplus intake (pro or con)*</td>
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<td><strong>Whole food sources of protein</strong></td>
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<td>Specialized diets (soy for vegetarians)</td>
<td>Lactose intolerant (some milk protein foods)</td>
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<td>Large variety of foods</td>
<td>Incomplete proteins (vegetable source)</td>
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<td>Physical properties in recipes</td>
<td>Fat and cholesterol content (pro or con)</td>
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<td>Personal preferences/compliance</td>
<td>Solids may reduce surplus intake (filling)*</td>
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<td>Filling/satisfying (pro or con)*</td>
<td>Preservative content (e.g., nitrates)</td>
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<td>Additional nutrients</td>
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<td><em>Liquids have faster gastric emptying and may be helpful for repeat intake and weight gain.</em></td>
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