Protein Fueling for Muscle Growth and Performance

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Course Objectives
After completing this course you will be able to:

- Explain how protein intake in relation to resistance exercise influences muscle growth.
- Explain how protein intake in relation to endurance exercise influences muscle growth and repair.
- Understand how carbohydrate may enhance muscle growth when consumed in conjunction with protein in relation to resistance exercise.
- Describe optimal nutrient composition of pre- or postexercise snacks to help enhance muscle growth.
- Recommend to your clients appropriate pre- and postexercise snacks for resistance and endurance training.

Ask bodybuilders what they eat to build muscle and they'll probably answer protein. Trainers and coaches will tell you that one of their most frequently asked question from clients is, "Should I eat more protein?" Is protein the fuel of choice for muscle development and performance? Protein is needed for muscle hypertrophy (muscle growth); however, additional dietary or supplemental protein will not add muscle mass, even with strength training, in the absence of adequate energy intake (*caloric* intake above maintenance needs). So what is the best recommendation for a client who wants to build muscle? Recent research shows that in conjunction with resistance exercise, the timing of protein intake (whether it is before or after exercise), protein quality (i.e., specific amino acids), and even consumption of protein with carbohydrate may be the key factors needed to enhance muscle growth (Borsheim et al., 2004; GSSI, 2002; Miller et al., 2003; Rasmussen et al., 2000; Tipton et al., 1999a; Tipton et al., 2001; Tipton and Wolfe, 2004).

The Role of Amino Acids

Quite simply, amino acids are the building blocks of protein. Twenty different amino acids combine in various arrangements to make up all the proteins in our body, including hormones, enzymes, and, of course, muscle tissue. Our bodies can produce the majority of these protein building blocks; however, nine amino acids must be obtained from diet and, thus, are considered *essential.* In order for our body to synthesize (build) any protein, including muscle tissue, all nine essential amino acids must be present. Therefore, it is important to choose protein-rich foods that will provide all nine essential amino acids. Such protein-rich foods include soy beans, skinless turkey and chicken, pork, lean red meat, and fish. Protein is also found in varying amounts in other plant-based foods such as grains, vegetables, and some fruits; however, these plant proteins do not individually provide all nine essential amino acids in the optimal amounts needed for protein synthesis by the body. A variety of plant-based proteins should be consumed daily to ensure adequate consumption of all nine essential amino acids.

Protein is most commonly consumed as a whole protein from a food or beverage source, but some athletes purchase protein supplements that provide amino acids, either individually or packaged containing combinations of all the essential amino acids. Importantly, all ingested protein must be broken down into its building blocks, amino acids, before being absorbed and used to synthesize bodily proteins.

Nine Essential Amino Acids (EAA)

- Phenylalanine
- Isoleucine
- Leucine
- Lysine
- Threonine
- Methionine
- Tryptophan
- Valine
- Histidine (conditionally essential)

Protein, Amino Acids, and Resistance Exercise

Protein was once thought to be the main energy source for muscle (VonLiebig, 1842). Today, it's recognized that carbohydrate is the main energy source, yet protein still plays an important role in muscle mass with relation to exercise. Exercise causes stress to muscle that can lead to muscle adaptation: breakdown, maintenance, and growth. The specific adaptation that occurs depends on the type of training as well as dietary intake. Protein, specifically essential amino acids (EAA), in conjunction with adequate energy intake (calories) can minimize muscle breakdown and stimulate muscle growth through a positive net muscle protein balance (Tipton et al., 1999b; Tipton et al., 2001; Tipton and Wolfe, 2004). A positive muscle protein balance when combined with appropriate strength/resistance training can elicit increases in muscle mass. This is the reason so many athletes wishing to gain muscle mass (and ultimately increased strength) base their diet on high intakes of protein-rich foods and even supplement with protein powders, pills, and drinks. Does all this extra protein really help? Let's take a look at the research.

Timing of Protein and Amino Acid Ingestion

Most athletes meet and often exceed the protein needs of muscle maintenance and growth (Tipton and Wolfe, 2004). Yet, gains in muscle growth in these athletes may be limited by the timing and composition (that is, essential or nonessential amino acid) of their protein intake.

Should protein (more specifically, individual amino acids) be consumed before or after resistance exercise? Research supports a benefit for intake at either time. Among healthy, recreationally active individuals, protein and/or individual EAA consumption within 1 hour following resistance exercise has been shown to result in muscle protein synthesis favoring muscle growth (Biolo et al., 1997; Borsheim et al., 2004; Rasmussen et al., 2000; Tipton et al., 1999a). Moreover, when healthy, recreationally active individuals were fed an amino acid-carbohydrate beverage (consisting of 6 grams EAA and 35 grams carbohydrate) *either* immediately before or after resistance exercise, consumption before

exercise was found to be more effective in promoting muscle protein synthesis (Tipton et al., 2001). While it is not clear why consumption of protein (whole or only the EAA) before exercise improved muscle protein synthesis more than after, it has been hypothesized that provision of amino acids (either directly or from the breakdown of a whole protein) beforehand allows for enhanced delivery of amino acids to muscle during exercise due to the increase in blood flow (Tipton et al., 2001). More amino acids to the muscle translates into more building blocks and thus the ability to increase muscle size. This finding suggests that the optimal timing of protein consumption is before resistance exercise if muscle hypertrophy is the goal. It is important to note, however, that both intake timings (before and after) have been shown to enhance muscle protein synthesis, so the preference of the athlete and availability of food may ultimately determine when to consume protein.

Composition of Protein and Amino Acid Ingestion

The composition of protein, whole or as individual amino acids, also appears to play a role in muscle protein synthesis. Tipton et al. (1999b) and Miller et al. (2003) demonstrated that not all amino acids are treated equally in relation to stimulation of muscle growth. Their research shows that only EAA are needed. What the optimal quantity and source (i.e., as part of whole protein or individual essential amino acids) of EAA is, as well as if consumption should be accompanied by carbohydrate or fat, is not currently known. What is known is that as little as 6 grams of EAA can enhance muscle protein synthesis when ingested before or after resistance exercise (Miller et al., 2003; Rasmussen et al., 2000; Tipton et al., 2001; Tipton and Wolfe, 2004). Whether these 6 grams of EAA should come from individual amino acid supplements or from a whole protein food source providing all EAA still needs to be determined. It has been suggested, however, that consuming 6 grams of EAA either way is sufficient (Miller et al., 2003; Tipton et al., 2001). Currently it is not known what the optimal dose of EAA is for maximal stimulation of muscle growth. Research has shown that protein synthesis did not differ in healthy volunteers consuming either 20 grams or 40 grams of EAA following resistance exercise (Tipton et al., 1999a). This finding suggests that a threshold may exist above which additional EAA consumption will not further enhance muscle protein synthesis. This latter point is important to acknowledge when counseling athletes and active individuals who desire to gain muscle mass – *more is not always better!*

Food sources that provide 6 grams of EAA: 1 cup lowfat milk or fruit-flavored yogurt**.**

In addition to consuming EAA as part of a pre- or post-resistance-exercise snack, adding a carbohydrate source may help further enhance muscle growth. Carbohydrate stimulates insulin release, and insulin has been shown to decrease muscle breakdown after exercise (Biolo et al., 1999; Tipton and Wolfe, 2004). In theory, when combined with EAA carbohydrate should enhance muscle growth. Research into this theory found that a drink combining 6 grams of EAA with 35 grams of carbohydrate increased muscle protein synthesis above that of a drink consisting of carbohydrate or EAA alone (Miller et al, 2003). The EAA-plus-carbohydrate drink contained slightly more calories than the carbohydrate-alone drink, making it is possible that the additional energy (calories) played a role in the higher observed muscle protein synthesis. This is unlikely, however,

because muscle protein synthesis was higher when EAA alone were consumed following resistance exercise compared with carbohydrate alone, despite the carbohydrate-alone drink containing more calories (Miller et al., 2003). Later research by the same group using equal-calorie drinks of EAA + protein + carbohydrate and carbohydrate alone still found that the former drink stimulated muscle growth more than the carbohydrate-alone drink (Borsheim et al., 2004). The combined effect of carbohydrate-stimulated insulin release helping to inhibit protein breakdown and amino acids' stimulation of muscle protein synthesis likely explains why consumption of both improves muscle growth (Tipton et al., 2001). Importantly, though, neither dietary regimen will promote muscle growth unless adequate overall caloric intake is maintained.

Calorie intakes for maintenance and muscle growth:

a) Approximate adequate calorie intake for muscle and body weight maintenance in resistance- trained athletes:
    a. 175 pound male = 3,000 calories per day
    b. 145 pound female = 2300 calories per day
b) Approximate adequate calorie intake for muscle growth (~1/2 to 1 pound per week) in resistance-trained athletes:
    a. 175 pound male = 3,000 calories per day + 250-500 calories
    b. 145 pound female = 2300 calories per day + 250-500 calories

One recent study evaluated how a whole protein (whey protein supplement) in combination with individual amino acids and carbohydrate influenced muscle protein synthesis (Borsheim et al., 2004). Findings from this study suggest that the peak anabolic (i.e., building) effects of both carbohydrate and individual amino acids may occur at different times. Protein synthesis is stimulated immediately by EAA ingestion; however, the anabolic properties of carbohydrate (a result of increased levels of insulin) lags behind. This suggests that to enhance the anabolic properties of both amino acids and carbohydrate, and thus the overall ability to stimulate muscle growth, carbohydrate intake should precede amino acid intake (Borsheim et al., 2004). Additionally, a complete protein (a whole-food or protein-drink providing all EAA) takes longer to digest and, therefore, when consumed at the same time with carbohydrate, may complement the peak anabolic effect of insulin better than individual amino acids (Borsheim et al., 2004; Miller et al., 2003). This is an area of deep importance in relation to making practical recommendations for food and beverage intake in relation to resistance exercise, and much more research needs to be done. Research needs to determine the best time to consume both carbohydrate and protein in relation to resistance exercise and whether the sources of carbohydrate and protein should come from whole foods/beverages or broken down as building blocks of each macronutrient, glucose and amino acids, respectively.

Protein and Endurance Exercise

While a typical bodybuilder munches on a meal of egg whites and chicken breast, a typical marathon runner consumes pasta with bread. Despite the focus on carbohydrate intake for endurance exercise, many endurance athletes have wondered how consumption of protein or specific amino acids before, during, or after exercise will affect their performance. Because most endurance athletes are concerned with maintaining and not

adding muscle mass (the added weight of excessive muscle mass slows down an endurance athlete), little has been done to explore whether protein consumption in relation to endurance exercise influences muscle breakdown/growth the same as it does resistance exercise. What has been shown is consumption of carbohydrate and protein post-endurance exercise leads to favorable conditions for muscle growth, including higher nitrogen balance (a positive nitrogen balance is needed for muscle growth) and enhanced amino acid uptake into muscle (Roy et al., 2002; Levehagen, 2001). When protein was added to a carbohydrate drink and consumed by elite athletes before, during, and after endurance exercise, protein balance was improved (decreased muscle breakdown, enhanced muscle growth) both during and after exercise above that of carbohydrate ingestion alone (Koopman et al., 2004). In fact, carbohydrate ingestion alone led to a negative protein balance, which could lead to muscle breakdown. While these results suggest that the addition of protein to a carbohydrate drink consumed in relation to endurance exercise may help maintain muscle mass, the study did not measure directly how the improved protein balance affected muscle mass/growth or, more importantly, performance. Additionally, because the addition of protein to the carbohydrate drink added extra calories, it is difficult to establish whether it was the added protein or the extra calories that improved protein balance.

Perhaps more interesting to an endurance athlete is how the consumption of protein in relation to exercise affects glycogen (carbohydrate energy stores) recovery after exercise. The optimal time to start replenishing spent glycogen stores is within the first 30-60 minutes following endurance exercise (Jentjens et al., 2001). Some have proposed that adding protein to a post-endurance-exercise meal or snack enhances glycogen replacement by promoting a greater insulin response. Insulin helps shuttle glucose into the muscles and liver to be stored as glycogen, so a greater response could translate into improvements in glycogen storage. While an interesting theory, there have been mixed results when evaluating if the addition of protein to a carbohydrate beverage does truly enhance glycogen storage following endurance exercise (Maughan and Burke, 2002). Some research found that consumption of protein with carbohydrate immediately following exercise led to an improvement in glycogen storage (Zawadzki et al., 1992). This research, however, did not control for calorie intake, thereby making it difficult to determine if added protein or extra calories improved glycogen replacement. Even research conducted with both beverages containing equal calories presented mixed results. Some found that the addition of protein enhanced glycogen storage (Ivy et al., 2002), while others did not (Carrithers et al., 2000; Jentjens et al., 2001; Tarnopolsky et al., 1997; van Loon et al., 2000). Differences in study design likely explains the disagreement and suggests that two factors may strongly influence whether the addition of protein to a carbohydrate beverage enhances glycogen recovery after endurance exercise. These factors include timing (interval of intake) and amount of carbohydrate. Studies that provided exercisers with either a carbohydrate-alone or carbohydrate-plus-protein beverage at frequent intervals (every 15 to 30 minutes) found no difference in glycogen storage (Carrithers et al., 2000; Jentjens et al., 2001; Tarnopolsky et al., 1997; van Loon et al., 2000), suggesting that more frequent consumption of carbohydrate may offset the benefit that additional protein could have in enhancing glycogen recovery. Further, research supports that when carbohydrate content of a post-recovery beverage is

very high (~0.5 grams of carbohydrate per pound of body weight), additional protein will not provide any further benefit to glycogen recovery (Jentjens et al., 2001). These findings, however, do not dismiss the potential benefit the addition of protein may have. One study found that when recovery time is limited for an athlete, such as occurs with back-to-back endurance events, the consumption of a carbohydrate-plus-protein beverage or snack immediately after exercise (within 10 minutes) improved glycogen recovery over that of a carbohydrate-alone beverage or snack consumed at the same time (Ivy et al., 2002). While the jury is still out on whether to add protein to a recovery beverage/snack, endurance athletes will benefit from these practices:

- Consume a high carbohydrate (at least 0.5 to 0.7 grams of carbohydrate per pound of body weight) immediately following exercise and then again 2 hours following exercise (*when possible*).
- Consume a moderate amount of high-quality protein (approximately 8-16 grams or the amount found in 1 cup lowfat milk or yogurt) with carbohydrate as part of a postexercise snack to provide amino acids for muscle repair and recovery and *potentially* enhance glycogen recovery.

Practical Guidelines

We are still years from establishing the exact dose response for optimal protein, or more specifically amino acid intake, to promote muscle growth in combination with resistance exercise. We can use the current research to provide some insight and make practical recommendations to our clients.

First, don't shell out lots of money for expensive protein powders, pills, shakes, and bars; instead turn to your fridge. One cup of lowfat chocolate milk or lowfat fruit yogurt will likely provide an athlete/active individual with the amount of EAA and carbohydrate they need to enhance muscle growth (GSSI, 2002).

For those who need more specific calculations for estimating quantity of protein and carbohydrate to consume, research recommends 0.045 grams of EAA per pound of body weight in combination with 0.23 grams of carbohydrate per pound of body weight (GSSI, 2002). For example: For a 130-pound woman this equals 5.9 grams of EAA and 30 grams of carbohydrate, or simply a cup of lowfat, fruit-flavored yogurt. A typical sports bar with 8-10 grams of protein (ideally from whey protein) and 30-45 grams of carbohydrate also provides the appropriate amount of protein and carbohydrate.

Pre- and Postexercise Snack Ideas for Combining Carbs and Protein [side bar]

- 2 slices whole grain toast and 2 tablespoons peanut butter
- apple and 1 cup lowfat cottage cheese*
- 1 cup fruit yogurt and 1/4 cup granola*
- 2-egg omelet with 1 cup fresh vegetables, 1 whole-wheat English muffin*
- string cheese and 1 ounce pretzels*
- 1/4 cup nuts and an orange
- hard-boiled egg and 1/2 whole-wheat bagel*
- whole-wheat pita and 1/2 cup canned tuna*
- energy bar and 8-ounce sports drink

*These food combinations provide higher quality protein (that is, protein with all the nine EAA).

Pre- or Post-Resistance Exercise:

- ***Specifically -*** Consume 6 grams (or 0.045 grams/ pound body weight) of EAA in combination with 35 grams (or 0.23 grams/ pound body weight) of carbohydrate within 1 hour of completing exercise.
- ***Practical Choices –*** Choose a serving of a complete protein source like low-fat (chocolate or plain) milk, yogurt, meats, fish, or poultry that will provide at least 0.05 grams of protein per pound body weight in combination with a carbohydrate source like cereal, bread, or sports drink.

Currently there is no research to support consumption of protein or amino acids during resistance exercise to help promote muscle growth.

Post-Endurance Exercise:

- ***Specifically -*** Consume a high carbohydrate (at least 0.5 to 0.7 grams of carbohydrate per pound of body weight) immediately following exercise and then again 2 hours following exercise (*when possible*).
- ***Practical Choices –*** Consume a moderate amount of high-quality protein (the amount found in 1 cup lowfat milk or yogurt) with carbohydrate snack after exercise to provide amino acids for muscle repair and recovery and *potentially* enhance glycogen recovery.

Daily Protein Intake:

- *Resistance Exercise* – Daily protein intake should be between 0.36 and 0.76 grams of protein/pound of body weight. Recreational resistance-training athletes should consume protein at the lower end of this range, and people engaged in heavy resistance training should consume closer to the upper range when muscle growth is the goal. Those wanting to maintain muscle mass should consume protein intake in the middle of the range. With everyone, protein intake will change with level of training and training goals; therefore, keep records of intake and adjust as necessary.
- *Endurance Exercise* – Daily protein intake should be between 0.36 and 0.72 grams of protein/pound of body weight. Beginning recreational endurance-training athletes should consume protein at the lower end of this range, and people engaged in extensive endurance training should consume closer to the upper range. Habitual recreational endurance athletes should consume protein intake in the middle of the range. With everyone, protein intake will change with level of training and training goals; therefore, keep records of intake and adjust as necessary.

Final Thoughts

The following factors should be considered for optimal muscle development and performance:

- Encourage optimal energy intake every day to ensure that the nutrients (amino acids and glucose) from a pre- or post-exercise protein and carbohydrate meal/snack are available to enhance muscle protein synthesis and not to be used as an energy source.
- Consider the source and quality of protein, oral AA supplements or, more practical, a complete protein with all EAA (milk, yogurt, meat, fish, poultry, soy).
- Time carbohydrate intake according to source and quality of protein:
    - A complete protein may be consumed with carbohydrate (chocolate milk).
    - EAA alone should be consumed following carbohydrate to ensure stimulation of protein synthesis is coordinated (lowfat, high-carbohydrate granola bar followed by an EAA supplement pill(s)).
- Consider optimal timing of intake, either immediately before or after exercise.

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Jaclyn (Jackie) Maurer, Ph.D., R.D., completed a bachelor's degree in food science and human nutrition at the University of Maine in 2000. Immediately following graduation she moved to Tucson, Arizona, to work on a master's degree in nutritional sciences at the University of Arizona. It was at this time that Jackie took over project coordination of the Combined Events Athlete Development project working with elite American USA track and field athletes. Jackie completed her master's research in 2001, which focused on the effects of exercise and hormone replacement therapy on bone mineral density in postmenopausal women (the BEST Study). She then completed a dietetic internship at the University Medical Center in Tucson in May 2003. In September of 2003, Jackie passed the American Dietetic Association National Registration Exam and became a registered dietitian. Following her internship, Jackie returned to graduate school at the University of Arizona and completed a doctoral degree in nutritional sciences with a minor in physiology in May 2005. Her doctoral research explored psychosocial factors associated with weight loss in overweight women.

While at the University of Arizona, Jackie worked with the College of Agriculture, Department of Nutritional Sciences, Cooperative Extension on outreach nutrition education and provided volunteer nutrition consulting for athletes at the University of Arizona and community presentations on sports nutrition to local running groups. Jackie is currently a Post-Doctoral Associate in the Department of Nutritional Sciences at Rutgers University in New Brunswick, New Jersey, where she teaches nutrition and health and continues to conduct research in outreach nutrition education. She is a member of the American Dietetic Association and the Sports, Cardiovascular Nutritionists and Weight Management Dietetic Practice Groups of the American Dietetic Association. Ms. Maurer was recently selected as one of Arizona's Registered Young Dietitians of the Year for 2004. On a personal note, Jackie is an avid runner and was a competitive distance runner from junior high school through college.

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