LEARNING OBJECTIVES

• To realize that following a strength training session muscle protein breakdown exceeds muscle protein synthesis, resulting in several hours of net negative protein balance.
• To recognize that ingesting supplemental protein before and/or after a resistance workout is essential for attaining a net positive protein balance that enhances the potential for muscle development.
• To review research-based information and recommendations for effective pretraining/posttraining protein/carbohydrate supplementation.

Key words: Strength Training, Muscle Development, Muscle Hypertrophy, Protein Intake, Nutritional Supplementation

There presently exists a disconcerting irony between the health risks associated with sedentary lifestyles and the small percentage of American adults who meet the minimal physical activity standards established by the American College of Sports Medicine and the American Heart Association in 2007 (30 minutes of moderate-intensity physical activity 5 or more days a week or 20 minutes of vigorous physical activity 3 days a week) (1). Recent research on the topic reveals that only 3.5% of our adult population attains this relatively low level of regular physical activity (25). There seems to be an even greater disconnection between the well-documented health benefits of resistance exercise and the lack of adult participation in strength training. In fact, a 2010 article in ACSM’s Current Sports Medicine Reports presented sufficient research evidence on the health-related outcomes of resistance training for the authors to recommend a public health mandate for resistance training (19). A 2012 review article by Wescott concluded that standard resistance exercise is effective in reversing muscle loss, recharging resting metabolism, reducing body fat, facilitating physical function, resisting diabetes, improving cardiovascular health, increasing bone mineral density, enhancing mental health, and reversing specific aging factors (27). A more complete list of resistance training benefits is presented in Table 1.

In inactive adults, muscle mass decreases by 3% to 8% per decade after age 30 years (8) and by 5% to 10% per decade after age 50 years (15), averaging about 1 lb of muscle loss per year after the fifth decade of life (17). Reduced muscle mass is largely responsible for reduced resting metabolism (18), which is typically accompanied by increased fat accumulation (32). Fortunately, resistance exercise has been shown to reverse muscle loss in adults of all ages (27), averaging approximately 1 lb per month increase in lean weight during the first several months of strength training (4,22,29,30). The importance of muscle remodeling and development has spawned numerous resistance exercise programs and strength training protocols.
for young, middle-aged, and older adults. In addition to experimenting with various training methods, several studies have examined the effects of preexercise/postexercise protein/carbohydrate consumption on muscle building and related resistance training outcomes.

**PRERESISTANCE/POSTRESISTANCE EXERCISE
PROTEIN SUPPLEMENTATION**

Protein is an essential nutrient that comprises approximately 22% of muscle tissue, with water contributing most of the remaining 78%. Although it is easy to assume that almost all Americans eat sufficient protein, about one quarter of 2,600 men and women aged 65 to 85 years studied in Maryland were consuming inadequate amounts of protein (4). The Recommended Dietary Allowance (RDA) for adults of all ages is 0.36 g of protein per pound of body weight or about 55 g of protein per day for a person who weighs 150 lbs. People older than 50 years who perform resistance exercise need at least 25% more protein than the RDA level to maintain their muscle mass and 50% more protein than the RDA level to increase their muscle tissue (4). As the amount of protein that can be consumed at one time without exceeding the anabolic maximum is not yet established, it is recommended that protein intake be distributed throughout the day (e.g., breakfast, lunch, dinner, and postexercise snack) rather than at a single protein-rich meal.

Based on numerous study findings, it would seem that the best time to ingest extra protein is just before or just after a strength training session because doing so significantly enhances muscle development (2,6,7,13,20,21). The muscle-building effects were perhaps best demonstrated in a study conducted by Paul Cribb, Ph.D., and Alan Hayes, Ph.D., from Victoria University (Australia) in 2006 (5). Seventeen fit young men (mean age, 22 years) performed the strength training programs 4 days a week for a period of 10 weeks. The resistance training consisted of high-intensity workouts using mostly compound exercises performed with free weights in a three-phase periodized protocol (70% to 75% 1 RM, 80% to 85% 1 RM, 90% to 95% 1 RM). All of the study participants consumed similar amounts of supplemental protein/carbohydrate twice each day on workout days only. Half of the subjects took the supplement immediately before and after each strength training session. The other half took the supplement in the morning and the evening, at least 5 hours from the time of the workout. All of the participants were prescribed 1 g of the supplement for every kilogram of body weight, so a 100-kg (220-lb) male would ingest 100 g of supplement twice each training day. The 100 g of supplement contained 40 g of protein, 43 g of carbohydrate, and 7 g of creatine monohydrate.

After 10 weeks of training, the study participants who took the protein/carbohydrate supplement preroworkout/postworkout gained significantly more lean weight than those who ingested the protein/carbohydrate supplement morning and evening (+2.8 kg vs. 1.5 kg). The preroworkout/postworkout supplement group also demonstrated significantly greater increases in bench press strength (+12.2 kg vs. 9.0 kg) and squat strength (+20.4 kg vs. 16.1 kg) than the morning/evening supplement group. In addition, the preroworkout/postworkout supplement subjects experienced significantly greater increases in type IIA muscle fiber cross-sectional area, type IIX muscle fiber cross-sectional area, and contractile protein content than did the morning/evening supplement group. Based on their findings, the authors concluded that supplement timing represents a simple but effective strategy to enhance the positive physiological adaptations that are associated with resistance training. The authors further suggested that this strategy should benefit most healthy adults who perform resistance exercise.

Other investigators (29) decided to test this hypothesis with previously untrained middle-aged and older adults (52 women and men aged 39 to 82 years) who completed a 36-week research program in 1 of 3 study groups. The control group did not exercise or take supplemental nutrition. The exercise-only group performed about 25 minutes of strength training (12 standard resistance machines; 1 set of 8 to 12 repetitions each) and about 25 minutes of aerobic activity (recumbent cycling). The exercise plus supplement group performed the same exercise program and
consumed a protein/carbohydrate shake immediately after each training session. The supplemental shake provided 24 g of protein and 36 g of carbohydrate. Only the exercise plus supplement group attained a significant increase in lean weight (50.3–52.7 kg). Based on these findings, it would seem that ingesting a protein/carbohydrate supplement immediately after strength training sessions enhances muscle development in middle-aged and older adults.

In addition to the positive results observed in young men (5) and middle-aged and older adults (29), studies have demonstrated that posttraining protein/carbohydrate supplementation can enhance the desired effects of resistance exercise in young women (13) and elderly men (7). According to John Ivy, Ph.D., and Lisa Ferguson, M.S., from the University of Texas, (12) postexercise protein/carbohydrate supplementation is an effective means of restoring muscle glycogen, repairing muscle damage, attenuating protein degradation, and initiating protein synthesis.

**PROTEIN PLUS CARBOHYDRATE OR PROTEIN ALONE**

Many of the studies on resistance training supplementation have used a combination of protein and carbohydrate (5–7,13,29). However, protein alone has been shown effective for increasing muscle fiber size (2), and some studies have indicated that adding carbohydrate to protein does not increase postexercise muscle protein synthesis (14,24). In contrast, a review by Jay Hoffman, Ph.D., concluded that “the combination of carbohydrate with protein or amino acids in a supplement may contribute to a more effective protein uptake and enhanced synthesis rate of muscle protein” (11). The authors of another research review article concluded that “Carbohydrates play a limited role in protein synthesis ...(but) are vital to replenish glycogen stores diminished from prolonged or high-intensity exercise” (21).

Researchers from the University of Texas have proposed that resistance exercise adaptations may be optimized by taking appropriate posttraining protein/carbohydrate supplementation (12). Based on their interpretation of the research, they recommend a supplement that provides 0.5 to 0.6 g of protein plus 1.0 to 1.2 g of carbohydrate per kilogram of bodyweight. As an example, they suggest that a person weighing 70 kg (154 lbs) should ingest a posttraining supplement that contains 35 to 42 g of protein and 70 to 84 g of carbohydrate.

**COMMERCIAL SUPPLEMENTS OR FOOD SOURCES**

Many of the preexercise/postexercise supplement studies have used commercial products to provide various combinations of protein and carbohydrate sources. However, other research has been conducted with readily available food such as whole milk, fat-free milk, and whole eggs. Research with men (10) and women (13) has demonstrated greater lean weight gain and greater fat weight loss with postexercise fat-free milk compared with those with a carbohydrate supplement. A similar study (31) compared skim milk with soy protein for promoting net muscle protein balance after resistance training. The results indicated that milk-based proteins promote muscle protein accretion better than soy-based proteins when ingested after resistance exercise. Another study (6) compared the effects of fat-free milk and whole milk taken 1 hour after resistance exercise on net muscle protein synthesis. When the quantities ingested were the same (237 g), whole milk was more effective than fat-free milk. However, when the calories ingested were the same (requiring 393 g of fat-free milk and 237 g of whole milk), there were no significant differences between fat-free milk and whole milk supplementation. In his research review, the findings on postexercise milk supplementation led Dr. Hoffman to conclude that “a food source such as milk appears to be suitable for ingestion during recovery from resistance exercise and may be a cheaper and effective alternative to protein supplements” (11).

Another study (16) examined the effects of ingesting different amounts of whole egg protein on muscle protein synthesis. The study participants ingested 0, 5, 10, 20, or 40 g of whole egg protein after lower body strength training sessions. Higher doses of protein produced correspondingly higher rates of muscle protein synthesis through the 20-g supplement. The 40-g dose did not generate more muscle protein synthesis, indicating that...
20 g of whole egg protein may represent an optimal amount of this postexercise supplement.

PROTEIN INTAKE AND PROTEIN TIMING

With the exception of older adults, most Americans attain adequate amounts of protein on a daily basis. However, researchers (33) have suggested that the quantity, quality, and timing of protein consumption are all important factors in muscle development. Progressive resistance exercise provides the stimulus for muscle development. However, the tissue micro-trauma resulting from a resistance training session requires sufficient protein to sustain the muscle-building processes that lead to increased strength and size (hypertrophy). Basically, muscle hypertrophy is dependent on a positive protein balance such that muscle protein synthesis exceeds muscle protein breakdown. Although resistance exercise increases the rate of muscle protein synthesis, it also increases the rate of muscle protein breakdown, resulting in a net negative protein balance for several hours after the training session (3). Of course, it is beneficial to promote a net positive protein balance as much of the time as possible. To experience a net positive protein balance after resistance exercise, it is necessary to consume supplemental protein in close proximity to the training session (preworkout/postworkout). In their review article, Chris Poole, M.Sc., and colleagues (21) stated that “It is necessary for individuals who seek to gain lean muscle mass to induce a positive protein turnover as often as possible. It has been confirmed that protein and/or amino acid ingestion is required to reach a positive protein/nitrogen balance.” Based on the research reviewed, these authors presented four key findings. First, resistance exercise increases both muscle protein synthesis and muscle protein breakdown. Second, the increase in muscle protein breakdown exceeds the rate of muscle protein synthesis. Third, consumption of dietary protein and/or amino acids after strength training sessions augments a net positive protein balance and enhances the potential for muscle hypertrophy over time. Fourth, ingestion of dietary protein and/or amino acids immediately after resistance training is more effective than postponed supplementation for enabling muscle hypertrophy.

Research also has shown that ingesting supplemental protein before a resistance training session elicits a significantly greater increase in resting energy expenditure 24 hours after the workout compared with that after ingesting supplemental carbohydrate (9). Therefore, it would seem that consuming supplemental protein, or protein/carbohydrate, in close time proximity to resistance exercise sessions may provide dual benefits of enhanced muscle hypertrophy and increased resting energy expenditure. This may be one reason why some studies have shown both greater muscle gain and greater fat loss for subjects ingesting supplemental protein, or protein/carbohydrate, at the time of their resistance training sessions (10,13,28).

SUMMARY

As reported in a previous issue of ACSM’s Health & Fitness Journal (26), research clearly reveals that resistance exercise is an effective means for rebuilding muscle, recharging metabolism, and reducing fat in previously inactive adults and older adults. The studies addressed in this article indicate that these training outcomes may be enhanced by ingesting supplemental protein, or protein and carbohydrate, near the time of the exercise session (just before, just after, or both). Based on these research findings, it would seem that pretraining/posttraining protein/carbohydrate supplementation can induce significantly greater increases in lean weight and resting energy expenditure and significantly greater decreases in fat weight than those after resistance exercise without supplementation. Although many studies have incorporated commercial protein/carbohydrate products, other studies have demonstrated significant body composition improvement from ingesting milk after the strength

<table>
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<tr>
<th>Body Weight, kg (lbs)</th>
<th>Protein Supplement, g</th>
<th>Carbohydrate Supplement, g</th>
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</thead>
<tbody>
<tr>
<td>50 (110)</td>
<td>18 - 22</td>
<td>28 - 32</td>
</tr>
<tr>
<td>60 (132)</td>
<td>22 - 26</td>
<td>34 - 38</td>
</tr>
<tr>
<td>70 (154)</td>
<td>26 - 30</td>
<td>40 - 44</td>
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<tr>
<td>80 (176)</td>
<td>30 - 34</td>
<td>46 - 50</td>
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<tr>
<td>90 (198)</td>
<td>34 - 38</td>
<td>52 - 56</td>
</tr>
<tr>
<td>100 (220)</td>
<td>38 - 42</td>
<td>58 - 62</td>
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Protein Supplements and Resistance Training

training sessions. Some experts have recommended that pre-training/posttraining supplements contain at least 0.5 g of protein and 1.0 g of carbohydrate per kg of body weight for optimum results (~35 g of protein and 70 g of carbohydrate for a 70-kg individual). However, studies have shown excellent responses to smaller supplement amounts (~24 g of protein and 36 g of carbohydrate) for subjects averaging 70 kg of body weight. Other research has demonstrated net muscle protein synthesis from postexercise servings of milk that contained about 8 g of protein and 12 g of carbohydrate. The available evidence indicates that desired resistance training results, such as muscle development, strength gain, and fat loss, may be enhanced by consuming supplemental protein/carbohydrate in close time proximity to the workout session. Based on the research results reviewed in this article, general guidelines for pretraining/posttraining protein and carbohydrate supplementation for exercisers of selected body weights are presented in Table 2.

References


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inactive adults lose muscle mass at the rate of 3% to 8% per decade, resulting in reduced resting metabolism and increased fat accumulation. progressive resistance exercise provides the stimulus for strength development, but muscle hypertrophy requires a net positive protein balance. an effective means for attaining posttraining net positive protein balance is supplemental protein (~10–40 g) consumed in close time proximity (≤1 hour) of the resistance workout. several studies have shown that pretraining/posttraining protein/carbohydrate ingestion enhances muscle development, strength gain, and fat loss in men and women of all ages.