Protein Applications in Sports Nutrition–Part II: Timing and Protein Patterns, Fat-Free Mass Accretion, and Fat Loss

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ABSTRACT

A NUMBER OF KEY CONSIDERATIONS EXIST REGARDING PROTEIN, INCLUDING OVERT REQUIREMENTS, QUALITY, AND DOSING. IN ADDITION, ATHLETES AND RESEARCHERS HAVE CLOSELY EXAMINED THE IMPACT OF PROTEIN AND NUTRIENT TIMING ON ACUTE AND PROLONGED ADAPTATIONS TO DIFFERENT TYPES OF EXERCISE WITH MIXED RESULTS. THE PATTERN OF MEAL AND PROTEIN CONSUMPTION SEEMS TO EXERT AN IMPACT ON CHANGES RELATED TO HEALTH, BODY COMPOSITION, AND MUSCLE PROTEIN SYNTHESIS. PROTEIN IS A KEY NUTRIENT FOR INDIVIDUALS LOOKING TO LOSE WEIGHT, REDUCE THEIR BODY FAT, AND IMPROVE THEIR HEALTH. FINALLY, PROTEIN INTAKE CONTINUES TO BE A KEY VARIABLE FOR ATHLETES LOOKING TO GAIN STRENGTH, POWER, AND FAT-FREE MASS.

OVERVIEW

Within sports nutrition, protein, a key macronutrient, continues to capture a great deal of attention. For a number of years, the notion that greater protein was required by exercising individuals was (and to some degree still is) a controversial topic. As anecdotal and empirical research began to accumulate to support its use, an appreciation for the utility of protein began to develop. In an attempt to further enhance the known benefits of consuming adequate amounts of the macronutrients, researchers began to explore nutritional strategies to further heighten favorable changes within exercising muscle by manipulating the time when nutrients were provided as well as different types of certain macronutrients. Initial timing research centered on carbohydrates. Several years later, research became focused on protein timing with recent investigators exploring the potential impact of altering the patterns of protein meals to stimulate increases in muscle protein synthesis (MPS) and promote improvements in health and body composition. Finally, the addition of protein as part of a resistance training program to further promote increases in strength and fat-free mass (FFM) continues to be one of the most popular applications of protein, particularly with athletes and other sectors of sports nutrition. In this light, the role of protein as a part of a weight loss program to better control appetite and feelings of satiety as well as to facilitate greater losses of body fat, while better maintaining levels of FFM continues to be seen as a greater empirical support from the available literature. The purpose of this brief review is to discuss available literature as it relates to topics such as protein timing, patterns of protein consumptions, and alterations in protein intake to facilitate adaptations related to FFM accretion and fat mass loss.

TIMING AND PROTEIN PATTERNS

Protein timing continues to be a popular strategy to enhance observed physiological adaptations to exercise. For a deeper discussion on the topic, reviews of varying viewpoints (4,30,52) and books (7,29,53) have been written regarding the concept, but it is important to highlight that research exists exploring all timing considerations involving both aerobic and resistance exercise in regards to carbohydrate and protein. Currently, little research exists examining the impact of timed protein ingestion surrounding aerobic exercise performance as the majority of this literature has involved resistance exercise. Without question, the impact of carbohydrate administration provided before a bout of prolonged endurance exercise holds great potential to improve parameters of endurance performance (15,62), but administration of protein or amino acids before endurance exercise is lacking in the literature. On considering known patterns of substrate utilization (carbohydrate and fat breakdown in favor of protein and amino acid breakdown during aerobic exercise) and the particular problems that can result from a digestive perspective with preaerobic exercise ingestion of protein and amino acids, the lack of literature is somewhat understood.

Ingestion of amino acids (as hydrolyzed protein) throughout a bout of endurance exercise in conjunction with carbohydrate delivery has been shown to improve subsequent muscle damage (e.g., creatine kinase) as well as time to exhaustion performance (50,51). Similarly, Miller et al. had 9 male runners complete 3 similar investigative trials involving a 2-hour run at 65% $\dot{V}O_2$max. Blood samples were collected in response to exercise and feeding then measured for changes in insulin, glucagon, epinephrine, norepinephrine, growth hormone, testosterone, and cortisol. Protein and amino acid ingestion resulted in significant increases in glucagon, as well as significant attenuations of free fatty acids and amino acid levels (44). However, these studies were not designed with the intention to examine the true impact of timing, thus the impact of protein timing per say on these outcomes remains somewhat undetermined. Protein or amino acid ingestion during the postexercise time period was initially shown by Zawadzki et al. (65), who found that rates of glycogen resynthesis are significantly greater when compared with just ingestion of carbohydrates. However, subsequent research has indicated that this effect is most evident when total ingestion of carbohydrate is lower than what is expected considering the athlete's activity level (12). Bolster et al. (9) had 5 endurance-trained male runners (21.3 ± 0.3 years; 179.1 ± 1.7 cm; 70.6 ± 0.1 kg; 70.6 ± 0.1 $mL \cdot kg^{-1} \cdot min^{-1}$) complete a 75-minute treadmill run at 70% $\dot{V}O_2$peak after ingesting diets of varying protein content (low protein, equal to the recommended daily allowance [RDA]: 0.8 g/kg; moderate protein, equal to 2.25× the RDA: 1.8 g/kg; high protein, equal to 4.5× the RDA: 3.6 g/kg) for a 4-week period. MPS was measured after the run, and significantly greater rates of MPS were found after each subsequent level of dietary protein intake (high protein > moderate protein > low protein), whereas no difference was found between moderate protein and low protein ($p > 0.05$).

For years, the majority of focus was put on consuming nutrients after a single bout of resistance exercise (4+ sets of 10 repetitions at 70–85% 1 repetition maximum [RM] with 2 minutes of rest between sets), and this continues to remain popular. However, in 2001, Tipton et al concluded that consuming an identical combination of carbohydrates (35 g) and essential amino acids (6 g) immediately before a single bout of resistance training (10 sets of 8 leg press repetitions at 80% 1RM and 8 sets of 8 leg extension repetitions at 80% 1RM) resulted in greater rates of MPS than immediate postexercise ingestion. Rest periods between sets were 2 minutes, and the entire exercise bout took ~45–50 minutes. Follow-up studies by Fujita et al. and Tipton et al. in 2007 refuted these original findings resulting in the conclusion that neither ingestion time point illustrates significant superiority over the other, as both can robustly stimulate maximal rates of MPS (21,56,58).

An overwhelming majority of research has explored the impact of ingesting various combinations of nutrients after a bout of resistance exercise. This research consistently demonstrates that ingestion of single doses (6–12 g) of the essential amino acids alone or in combination with carbohydrates maximally stimulates rates of MPS and improves muscle protein balance (10,11,57), particularly when ingestion occurs immediately after or within 3 hours of completing a resistance exercise bout. In summary, little dispute arises regarding the ability of essential amino acids with or without carbohydrate immediately after, 1, 2, or 3 hours after exercise to maximally stimulate increases in MPS (11,28,57–59).

Numerous studies are available that have provided protein alone or in combination with carbohydrate after resistance training bouts over the course of several weeks. Collectively, results from these studies indicate that providing a 15–40 g dose of high-quality protein in conjunction with heavy resistance training facilitates improvements in strength, endurance, power, and body composition (17,23,34,49,63). Moreover, an excellent meta-analysis by Cermak et al. supports the notion that an increased intake of protein is favorable toward resistance training adaptations, such as strength and FFM gains (13).

Although studies have provided nutrients after a workout bout and examined outcomes, very few studies have been designed with the explicit purpose to examine the impact of protein timing on the adaptations made by several weeks or months of resistance training. In this respect, 2 recently published well-constructed reviews by Aragon and Schoenfeld (4,52) are available to the interested reader that highlight the impact of postexercise timing of protein. Andersen et al. had participants consume isocaloric amounts of carbohydrate or protein immediately before and immediately after the last set of resistance training over 14 weeks and examined changes in performance and muscle cross-sectional area. Supplements were ingested first thing in the morning on nonworkout days. Timed ingestion of protein led to greater increases in hypertrophy when compared with timed ingestion of carbohydrate (2). One year later, in 2006, Cribb and Hayes published their findings that provided what seemed to be the strongest evidence for protein timing. Over the course of several weeks, 2 groups ingested identical amounts of protein, carbohydrate, and creatine (32 g protein, 34.4 g carbohydrate, 5.6 g creatine for a 80-kg participant), but 1 group ingested the protein and carbohydrate combination immediately before and after their workouts. The other group ingested the protein and carbohydrate combination before breakfast and shortly before going to bed on workout and evening on workout days. In addition, all participants trained between 3 and 6 p.m. and approximately 1–2 hours passed between the completion of their workout and their evening meal (16). Both groups experienced favorable increases in strength and lean body mass (LBM), but when nutrients were ingested at times closely surrounding each training bout significantly greater increases in LBM, maximal strength and muscle cross-sectional area were realized (16). In 2009, researchers used a very similar study design using trained collegiate athletes and reported no differences in performance or body composition between 2 groups of athletes ingesting protein close to each workout and identical amounts of nutrients in the morning and evening of training days (24). Conclusions from this work highlight the impact of consuming adequate amounts of protein on a daily basis whereby the participants in the second study were consuming higher amounts of calories and protein. Thus, it seems that overall protein intake may be operating as a more powerful factor when compared with timely consumption, although timing closely surrounding workouts does not hinder training outcomes.

The pattern of protein consumption has been increasingly investigated as well and in many respects, can be viewed as an extension of nutrient or protein timing. Two published studies from the same group of study subjects revealed that in response to a single bout of resistance exercise in healthy subjects, an intermediate sized dose (20 g) of whey protein isolate ingested every 3 hours over a 12-hour study window led to the greatest improvements in the overall balance of protein in the body and greater synthesis rates of protein found in skeletal muscle (6,45). From a health and fat loss perspective, Arciero et al. invoked a controlled pattern of protein feeding with 3 daily 20-g doses of whey protein at prescribed times to overweight study participants and combined it with no exercise, a resistance training program, or a combination of different types of exercise programs (high-intensity intervals, resistance training, interval sprint training, yoga, stretching or Pilates). Both exercise programs completed 4 workouts sessions per week. Outside of the prescribed protein feedings, all participants were instructed to follow their typical dietary practices and not alter their caloric intake or macronutrient distribution of foods consumed in their daily diet. The lack of a control group precluded the ability to determine the actual impact of protein feeding patterns, but of greatest importance, all groups lost significant amounts of weight and fat mass (5).

FAT-FREE MASS

The combination of muscular loading through resistance training and protein feeding is known to instigate widespread intramuscular changes that result in the accretion of FFM (13,48). Proteins are simultaneously being synthesized and degraded providing the basis for skeletal muscle's plastic response to loading (i.e., resistance training) (48). Protein ingestion increases MPS and reduces rates of muscle protein degradation seen in response to resistance exercise facilitating a positive muscle protein balance and setting the stage for the accretion of muscle mass (14). For this reason, supplementation with protein is used during periods of resistance training to optimize enhancements in FFM. Over time, MPS stimulated by protein ingestion results in protein accretion and may lead to hypertrophy when coupled with resistance training (47). Thus, increases in LBM are the result of chronic resistance training and provision of amino acids and/or protein, which results in a robust increase in net protein balance (32).

In a study by Cribb et al. (2007), 10 recreational bodybuilders were given a total dose of 1.5 $g \cdot kg^{-1} \cdot d^{-1}$ consisting of either whey isolate protein, protein + carbohydrate or protein + carbohydrate + creatine while participating in a high-intensity, 3-phase resistance training program for 10 weeks (18). Subjects consumed the prescribed supplement dose in 3 equal servings (0.5 $g \cdot kg^{-1} \cdot d^{-1}$) throughout the day (i.e., midmorning, posttraining, and before sleep); total dietary intake ranged from 1.6 to 2.3 $g \cdot kg^{-1} \cdot d^{-1}$. The supplementation of whey isolate led to an LBM increase of approximately 5 kg at the end of the 10-week training period. In another study, Cribb et al. (17) investigated the effects of whey as well as casein protein supplementation on FFM. Thirteen recreational bodybuilders supplemented with either 1.5 $g \cdot kg^{-1} \cdot d^{-1}$ of whey isolate or casein protein for 10 weeks while engaging in high-intensity resistance training. The supplement dose was divided into smaller equal servings (i.e., breakfast, lunch, posttraining, and dinner). Lean mass was significantly greater over the 10-week training period in the whey isolate group, with an LBM gain of 5 kg, whereas the casein group also illustrated a near 1-kg increase in LBM. Willoughby et al. investigated the combined effects of protein and amino acid supplementation after 10 weeks of heavy resistance training. Ten untrained males consumed a 14-g combination of whey and casein protein along with 6 g of amino acids, whereas 9 men were given an isocaloric placebo beverage of 40 g of dextrose. Ingestion occurred 1 hour before training and immediately after training. Subjects consuming the blend of protein and amino acids displayed significantly greater increases in FFM (5.62 ± 0.98 kg) versus the placebo group (2.7 ± 1.31 kg), respectively. Burke et al. (2001) reported a significant 2.3-kg increase in LBM in recreationally trained men after supplementing with 1.2 $g \cdot kg^{-1} \cdot d^{-1}$ of whey protein (in 4 equal servings) during 6 weeks of resistance training. Finally, 2 studies published by Kerksick et al. examined the impact of protein supplementation on changes made while resistance training over several weeks. The first study published in 2006 reported that college-aged men who consumed a 48-g blend of whey and casein protein experienced significant gains in LBM and strength while after a 10-week split-body (2 upper-body and 2 lower-body workouts per week, 6–12RM) resistance training program (34). In 2007, Kerksick et al. (33) used the same resistance training program over a 12-week time period and supplemented 49 healthy men and women with various combinations of protein and found that all groups experienced significant increases in strength and LBM; however, no carbohydrate placebo group was included in this study, as researchers were examining the impact of various sources of protein with and without the addition of creatine monohydrate. An upper limit of optimal protein intake to modulate body composition changes, while resistance training is currently unknown. Although the majority of published studies have used relative protein prescriptions of 1.2–2.0 $g \cdot kg^{-1} \cdot d^{-1}$ or absolute individual protein doses ranging from 10 to 40 g per day delivered in 1–3 doses, a study published in 2014 by Antonio et al. reported that participants consuming a hypercaloric diet at a protein dose of 4.4 $g \cdot kg^{-1} \cdot d^{-1}$ (>5× the RDA for protein) did not result in fat mass gains and also promoted increases in body mass and FFM (3). Although more research is needed, these results open the door for more research to explore even higher intakes of protein to examine what seems to be a unique role for protein to favorably impact body composition (Table 1).

Moreover, a meta-analysis by Cermak et al. outlined the effects of 22 randomized controlled studies that included 680 subjects and reported that compared with a placebo, protein supplementation significantly augmented FFM gain (+0.69 kg; $p < 0.001$) and strength (+13.5 kg, $p < 0.005$) during prolonged periods (12 ± 5 weeks) of resistance training in both younger and older adults. These results provide sound evidence that protein supplementation, or adequate protein intake, is required to maximize the physiological adaptations made in response to prolonged resistance training.

In summary, muscle protein accretion in response to resistance exercise is the result of successive periods of positive muscle protein balance (23). Amino acids found in protein represent the primary effectors of skeletal muscle protein metabolism through their ability to stimulate increased rates of MPS, suppress breakdown, and promote a net positive protein balance (14). The provision of essential amino acids favorably influences muscle protein balance over a 24-hour period by eliciting changes in muscle protein turnover (49). Protein supplementation (whey, casein, and amino acids in particular) impacts the regulation of muscle mass (25) stemming from the resultant net positive protein balance (14,35). Finally and most convincingly, LBM gains occur in trained and untrained young populations and older adults after periods of concurrent resistance training and protein supplementation (13). Thus, protein supplementation serves as an empirically based means to maximize enhancements in FFM during periods of resistance training with anticipated improvements ranging from 1 to 3 kg over approximately 12 weeks.

FORFEIT THE FAT, MAINTAIN THE LEAN: OPTIMIZING WEIGHT LOSS WITH PROTEIN

Weight loss through diet, exercise, or a combination can confer a host of benefits, including decreased cardiovascular disease risk, improved blood lipid profile, and improved body composition. For individuals seeking to lose weight, energy-restricted or hypoenergetic diets are needed to induce weight loss, but if restriction is severe, the potential for skeletal muscle atrophy and losses in LBM occur. Research by Layman and Kerksick reveals that caloric prescriptions in women that range from 1,200 to 1,600 calories per day in combination with resistance-based exercise programs at a frequency of 3–5 d/wk for 90–150 minutes per week can promote progressive weight loss without sharp reductions in FFM (27,32). Restriction of caloric intake below these levels (500–1,000 kcal/d) is likely to induce sharp reductions in body mass, with a significant proportion of weight loss coming from LBM. Weight loss of this type can negatively impact metabolic rate and in athletic populations, recovery, and performance (36,43), largely due to the reduction seen in FFM. In addition to protein's ability to spare loss of FFM while restricting calories, protein also helps in dieting individuals due to its slower overall digestibility when compared with carbohydrate and fat and its greater impact on satiety (40).

For these reasons, it is commonly accepted that skeletal muscle plays a vital role in maintaining metabolic rate and in the performance of strength, power, and endurance events, suggesting that a loss of muscle may have negative metabolic and performance outcomes. Moreover, skeletal muscle loss and the associated negative downregulation of one's metabolic rate are both commonly implicated in the plateauing of weight loss and regain after caloric restriction (26). In this respect, elevated intakes of protein (1.5–2.5 × the RDA: 1.2–2.0 $g \cdot kg^{-1} \cdot d^{-1}$), particularly in the face of caloric restriction and a basic resistance training

Table 1
Selected studies investigating the effect of protein supplementation on FFM

Author	*n*	Protein type (amount)	Resistance-trained state	RT program	Training load	Δ Change in FFM (kg)
Burke et al. 2001 (10)	10	Whey (1.2 $g \cdot kg^{-1} \cdot d^{-1}$)	≥3 y weight training experience	4 d/wk, 6 wk	4 sets/10–12 repetitions (8 d)	+2.3
					4 sets/8–10 repetitions (8 d)	
					5 sets/6–8 repetitions (8 d)	
					4 sets/8–10 repetitions (8 d)	
					4 sets/10–12 repetitions (8 d)	
Cribb et al. 2006 (13)	6	Whey isolate (1.5 $g \cdot kg^{-1} \cdot d^{-1}$)	Recreational bodybuilders, ≥2 y experience	3 d/wk	2 sets/8–10RM (70–75% 1RM; wk 1–2)	+5 (±2.8)
	7	Casein (1.5 $g \cdot kg^{-1} \cdot d^{-1}$)		10 wk	2 sets/6RM (80–85% 1RM; wk 2–4)	+0.8 (±2.4)
					2–3 sets/4RM (90–95% 1RM; wk 5–10)	
Cribb et al. 2006 (12)	10	Whey isolate (1.5 $g \cdot kg^{-1} \cdot d^{-1}$)	Recreational bodybuilders	10 wk	10RM (wk 1–2)	+4.9 (±2.5)
					8–6RM (wk 3–6)	
					6–4RM (wk 7–10)	
Fry et al. 2003 (20)	5	Whey (31.5 g) and casein (43.5 g)	Recreationally trained	4 d/wk	4 sets/8–10 repetitions (70–85% 1RM)	+1.6 (±6.5)
		Whey (7.5 g), casein (7.5 g) and colostrum (60 g)		12 wk		+1.3 (±5.9)
Hartman et al. 2007 (19)	18	Fat-free fluid milk (17.5 g)	Untrained	5 d/wk	2 sets/10–12 repetitions (wk 1–2)	+3.9 (±1.7)
				12 wk	3 sets/10–12 repetitions (wk 3–5)	
					4 sets/8–10 repetitions (wk 6–7)	
					4 sets/6–8 repetitions (wk 8–10)	+2.4 (±2.5)
	19	Fat-free soy protein (17.5 g)			4 sets/4–6 repetitions (wk 11–12)	
Kerksick et al. (34)	15	Whey (40 g), 5 g L-glutamine, and 3 g BCAAs	>1 y experience	4 d/wk	3 sets/10 repetitions (wk 1–4)	−0.1 (±11.5)

Table 1 (continued)

				10 wk	3 sets/8 repetitions (wk 5–8)	
					3 sets/6 repetitions (wk 9–10)	
	10	Whey (40 g) and casein (8 g)			Abdominal crunch: 3 sets/25 repetitions wk 1–10	+1.8 (±8.9)
Kerksick et al. (33)	12	Whey (31.5 g) and casein (43.5)	>1 y experience	4 d/wk	3 sets/10 repetitions (wk 1–4)	+0.8 (±13.5)
				12 wk	3 sets/8 repetitions (wk 5–8)	
					3 sets/6 repetitions (wk 9–12)	
	13	Whey (7.5 g), casein (7.5 g), and colostrum (60 g)			Abdominal crunch: 3 sets/25 repetitions wk 1–12	+1.6 (13.6)
Lemon et al. 1992 (41)	12	Habitual diet + casein and free amino acids (2.62 g/kg)	Novice bodybuilders	6 d/wk	4 sets/≤10 repetitions (70–85% 1RM)	+0.1
				4 wk		
Willoughby et al. 2007 (53)	10	Whey and casein (14 g), free amino acids (6 g)	Untrained	4 d/wk	3 sets/6–8 repetitions (85–90% 1RM)	+5.62 (±10.33)
				10 wk		

FFM = fat-free mass; RM = repetition maximum.

program are commonly being used to help attenuate FFM losses and promote progressive weight loss. Whether the individual is overweight and interested in weight loss or an athlete interested in enhancing their performance, the question often surfaces: What amount of each macronutrient, and more specifically protein, should an individual consume to achieve weight loss, yet maintain skeletal muscle mass? Fortunately, a good deal of published literature is available discussing the optimal macronutrient profile that promotes fat loss while synergistically maintaining (or increasing) LBM, resulting in improved body composition overall (31,38,55).

An early study by Walberg-Rankin (61) found that males who resistance trained and consumed low energy (18 kcal/kg) isocaloric diets containing either moderate (0.8 $g \cdot kg^{-1} \cdot d^{-1}$) or higher amounts of protein (1.6 $g \cdot kg^{-1} \cdot d^{-1}$) for just 7 days lost approximately 3.8 kg. However, body protein assessed through nitrogen balance (NBAL) indicated that the moderate-protein group exhibited a negative NBAL of −3.19 g/d, whereas the high-protein group had a positive NBAL of 4.13 g/d (61). Briefly, a positive NBAL indicates that more protein is being consumed than what is being excreted by the body and is associated with greater maintenance of LBM levels. Later, Skov et al. (54) used a diet-only approach to examine if a higher protein diet would cause superior weight loss in nonathletic, overweight, and obese individuals. Participants consumed a reduced calorie diet providing low (12% of energy) or high (25% of energy) amounts of protein. After 6 months, those consuming the higher protein diet lost more weight (8.9 versus 5.1 kg) and more body fat (7.6 versus 4.3 kg) when compared with individuals ingesting lower amounts of dietary protein. Interestingly, 35% of the subjects in the higher protein group lost more than 10 kg, compared with only 9% of the lower protein group (54). Since that time, research examining high-protein diets on weight loss and body composition improvements (lowered fat mass and increased or maintained FFM) in conjunction with exercise have boomed. A summary of these studies is provided in Table 2, but numerous studies are available that highlight the impact of restricted caloric intake levels with higher amounts of protein and in particular the power of combining this dietary approach with an exercise program. Research by Layman et al. (37) reported that overweight adult women who ingested a restricted calorie diet with a protein-to-carbohydrate ratio of 1:4 (125 g of protein day) lost a significantly greater amount of weight as fat mass and displayed improvements in cholesterol, triglycerides, and satiety, whereas another similar study by the same research group reported improvements in glucose and insulin status in the individuals who consumed higher amounts of protein (40). Finally, the combination of a restricted calorie diet with higher amounts of dietary protein in combination with exercise is the most powerful weight loss stimulus (55), a concept powerfully illustrated by a study published where 4 groups of overweight women followed a diet that was higher in either dietary carbohydrate or dietary protein with or without an additional exercise program for a period of 4 months (38). As before, the women who consumed a restricted calorie diet higher in protein demonstrated greater improvements in weight loss and fat loss; the effect was further enhanced when an exercise program was combined with this dietary approach (38).

As illustrated throughout Table 2, evidence exists for the favorable impact of higher dietary protein intakes toward the maintenance of LBM during hypoenergetic weight loss in overweight and obese populations (19,28,31,37,38,42,46), especially with a protein intake exceeding 30% total calories (1,8). Caloric restriction and weight loss in athletes is a popular issue in weight-class sports (i.e., wrestling, boxing, judo, etc.) or those activities that have an aesthetic component to them (i.e., gymnastics, dance, synchronized swimming, diving, etc.), but must be approached with caution regardless of the type of athlete. Toward this aim, severe caloric restriction in an athlete who is involved in high volumes of training, practice, and competition can negatively impact performance, promote loss of FFM, hinder recovery, increase susceptibility to illness, and set the stage for overtraining. In addition, coaches and athletes should also be aware of the psychological burden associated with caloric restriction. Fundamentally, the process of weight loss is no different than any other population, but with pressure from coaches to lose weight as quickly as possible, the recipe for concern becomes evident. For this reason, athletes are encouraged to work hard to lose weight and modify their body composition to meet such goals during the off-season and even then, the rate of weight loss must be adjusted to allow for increases in skill development and physical performance. A few studies do exist that have targeted diet approaches in active and athletic populations. For example, Pasiakos et al. (47) compared diets providing protein at 0.8, 1.6, and 2.4 $g \cdot kg^{-1} \cdot d^{-1}$, 1×, 2×, and 3× the RDA for protein, respectively, while achieving a 40% energy deficit through diet and exercise in physically active military personnel for a 3-week period. Participants lost an average of 3.2 kg regardless of group, but the proportion of weight loss due to specific changes in FFM and fat mass was most favorable in those individuals whose dietary protein intake was 1.6 and 2.4 $g \cdot kg^{-1} \cdot d^{-1}$. Furthermore, Mettler et al. (43) examined the influence of dietary protein status on changes in body composition and performance during a short-term hypoenergetic diet in competing athletes. The athletes were fed a hypoenergetic diet (60% of habitual energy intake), containing either 15% (~1.0 $g \cdot kg^{-1} \cdot d^{-1}$) protein or 35% (~2.3 $g \cdot kg^{-1} \cdot d^{-1}$) protein for 2 weeks. The results indicated that greater protein consumption led to a significantly superior maintenance of LBM when compared with the lower protein intake, whereas performance outcomes (1RM bench press, squat jump, maximal isometric leg extension, endurance bench press, and Wingate) were not altered, regardless of diet (43). Finally, an excellent study by Garthe et al. over 1 year examined the impact of 2 different rates of weight loss (both were slower than what is typically achieved for nonathletes) and found that after 6 months of dieting, a slower rate of weight loss facilitated greater levels of lean mass and strength, but after 12 months, the amount of weight lost, body composition, and performance changes were similar (22). An excellent review on weight loss considerations in athletes was published by Turocy et al. as a position stand for the National Athletic Trainers Association (60).

To extend the practicality of our article, a brief discussion will be included highlighting absolute amounts of calories and protein consumed during published weight loss studies. For example, Layman's classic block design involved diets with higher carbohydrate and higher protein amounts with and without the addition of exercise and required the women (45–47 years; 79.8–91.1 kg; 30.2–35.4 kg/m^2) in their research to ingest approximately 1,700 calories per day. The higher carbohydrate diet delivered protein at 0.8 $g \cdot kg^{-1} \cdot d^{-1}$ (15% total caloric intake) and lipids at 30% of total caloric intake. The carbohydrate:protein ratio in this diet group was >3.5. However, the protein group delivered protein at 1.6 $g \cdot kg^{-1} \cdot d^{-1}$ (~30% total calories) and fat remained at 30% total calories. The carbohydrate:protein ratio for this diet group was subsequently <1.5. Both diets delivered the same absolute amount of calories (~1,700 calories), total fat (~57 g/d), and fiber (~17 g/d). This dietary approach was combined with a modest exercise program consisting of 150 min/wk (30 minutes for 5 d/wk) of walking and a whole-body resistance training program 2 d/wk (7 machine-based exercises for all major muscle groups, one 12RM set was performed on each exercise).

Table 2
Selected studies investigating high-protein versus low-protein diets on weight loss in various populations

Author	Population of subjects	Duration	Diet intervention	Weight loss (kg)	Conclusions
Walberg, 1988 (52)	Recreational weight lifters	7 d	Hypoenergetic diets (18 kcal/d)	3.8	Hypoenergetic diet providing twice the RDA for protein (1.6 $g \cdot kg^{-1} \cdot d^{-1}$) was more effective in retaining body protein in WL than a diet with higher carbohydrate but the RDA for protein
			Group 1: 0.8 g PRO/kg/d		
			Group 2: 1.6 g PRO/kg/d		
Skov, 1999 (45)	Overweight and obese men and women	6 mo	Ad libitum fat-reduced diets (30% of total energy)	Group 1: 5.1	Replacement of some dietary carbohydrate by protein in an ad libitum fat-reduced diet improves weight loss and increases the proportion of subjects achieving a clinically relevant weight loss
			Group 1: high carbohydrate, 12% protein	Group 2: 8.9	
			Group 2: high protein, 25% protein		
Kerksick, 2009 (27)	Sedentary, obese women	14 wk	CON: no exercise, no diet	VLCHP: 5.2	Greatest improvements occurred when carbohydrate was replaced with protein in the diet. All groups improved muscular fitness, no difference between groups
			ND: no diet, exercise	LCMP: 4.0	
			HEHCLP: 2,600 kcal, 55:15:30%	HCLP: 3.8	
			VLCHP: 1,200 kcal, 63:7:30%		
			LCMP: 1,200 kcal, 50:20:30%		
			HCLP: 1,200 kcal, 55:15:30%		

(continued)

Table 2
(continued)

Mettler, 2010 (36)	Resistance-trained athletes	2 wk	Hypoenergetic (40% energy reduction)	Group 1: 3.0	35% protein was significantly superior to 15% energy protein for maintenance of LBM during short-term hypoenergetic weight loss
			Group 1: ~1.0 $g \cdot kg^{-1} \cdot d^{-1}$, 15% PRO	Group 2: 1.5	
			Group 2: ~2.3 $g \cdot kg^{-1} \cdot d^{-1}$, 35% PRO		
Josse, 2011 (24)	Healthy, overweight, and obese women	16 wk	HPHD (30% PRO and 15% dairy)	4.3	HPHD group: greater total fat and visceral fat losses, greater lean mass gains, and increases in strength despite similar body weight loss between all groups
			APMD (15% PRO and 7.5% dairy)		
			APLD (15% PRO and <2% dairy)		
Wycherley, 2012 (64)	General population	Meta-analysis 12.1 ± 9.3 wk	Hypoenergetic diets, which were isocaloric	Group 1: −0.8	Compared with the standard protein, high-protein diets caused a 0.87 kg decrease in FM and mitigation of reductions in FFM, 0.43 kg
			Group 1: high protein, low fat		
			Group 2: standard protein, low fat		
Pasiakos, 2013 (47)	Physically active military personnel	3 wk	Hypoenergetic (40% energy reduction)	3.2	Proportion of WL due to reduced FFM was lower and the loss of FM was higher in those receiving 1.6 and 2.3 $g \cdot kg^{-1} \cdot d^{-1}$
			Group 1: 0.8 $g \cdot kg^{-1} \cdot d^{-1}$		
			Group 2: 1.6 $g \cdot kg^{-1} \cdot d^{-1}$		
			Group 3: 2.3 $g \cdot kg^{-1} \cdot d^{-1}$		

APLD = adequate protein, low dairy; APMD = adequate protein, medium dairy; CON = control; FFM = fat-free mass; FM = fat mass; HCLP = high-carbohydrate, low-protein diet; HEHCLP = high-energy, high-carbohydrate, low-protein diet; HPHD = high protein, high dairy; LBM = lean body mass; LCMP = low-carbohydrate, moderate-protein diet; ND = no diet; PRO = protein; RDA = recommended daily allowance; VLCHP = very low carbohydrate, high-protein diet; WL = weight loss.

A close investigation of the Figure revealed significant changes in body fatness for both higher protein groups and when exercise was added, even greater amounts of fat were lost. Kerksick et al. used diets that ranged in caloric intakes (1,200–1,600 kcals/d) and protein intake (15–63% protein) over a 14-week period in obese women and found greater weight and fat loss when higher protein intakes were consumed. Although the majority

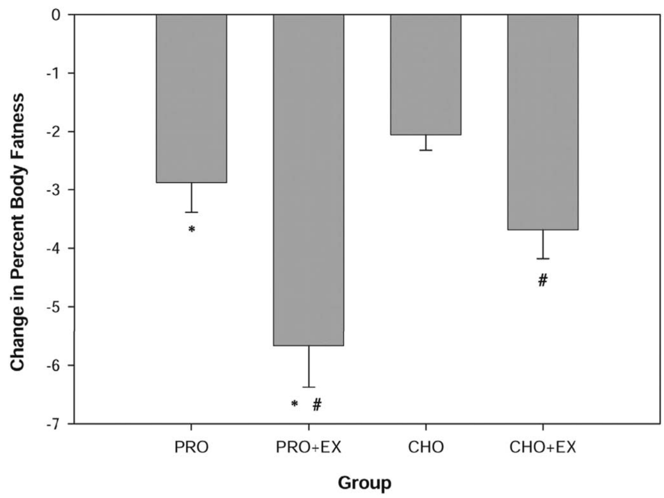

Figure. Changes in relative body fatness (%fat) for adult women after 16 weeks of consuming reduced-energy diets with a ratio of carbohydrates:protein >3.5 (CHO) or <1.5 (PRO) with or without a supervised exercise program (EX: 5 d/wk walking and 2 d/wk resistance training). Values are mean ± SEM, $n = 12$. *Significant main effect of diet, $p < 0.05$. #Significant main effect of exercise, $p < 0.05$. Used with permission. Original source: Layman DK, et al. *J Nutr* 1903–1910, 2005.

of weight loss literature has used women as study participants, prescribed hypoenergetic levels in men are commonly between 1,800 and 2,200 calories (55) with similar amounts and distribution of the macronutrients. Thus, people interested in applying these findings in women might start with a caloric prescription of approximately 1,500–1,700 cal/d with protein contents around 30–40% of total caloric intake, whereas in men, suggested values may be 1,800–2,000 calories with similar protein contents. These approximations are only starting points, and from there, the practitioner must monitor compliance, energy, and body composition changes and adjust initial caloric and protein levels accordingly.

In summary, when consuming a reduced-energy diet, the content of protein as well as overall energy intake strongly impacts the degree to which fat and FFM are lost from the body. In general, athletic or nonathletic individuals, regardless of body mass index status, who are aiming to decrease their body weight, may be advised to keep protein intake high ($\geq$1.5 $g \cdot kg^{-1} \cdot d^{-1}$). This diet strategy will allow individuals to mitigate losses of LBM, which over extended periods of restricted energy will sustain metabolic rate levels and promote greater losses of fat mass while maintaining performance.

CONCLUSIONS

Protein is an important nutrient that should be consumed in higher amounts by most individuals, particularly exercising individuals. Additional considerations of protein as they relate to timing and meal patterns continue to garner a great deal of attention. Although more research is needed, current findings indicate that protein consumption surrounding a workout has the potential to impact adaptations to exercise training, particularly when total protein intake does not meet bodily demands. Other work suggests that consuming a regular distribution of protein across the day may promote favorable changes in MPS and markers of health. As an approach to lose weight, diets that are restricted in calories and higher in protein consistently indicate favorable, and in many cases, greater improvements in weight loss and fat loss as well as maintenance of LBM. Similarly, elevated protein and amino acid intake in conjunction with resistance exercise is the most effective stimulus to instigate favorable improvements in FFM and strength.

In conclusion, the following take-home points are provided:

- From a timing of nutrients perspective, research involving both protein and carbohydrate indicate that total absolute intake is an important consideration. In both instances, any beneficial impact of protein timing seems to be diminished (or eliminated altogether) when absolute intake of protein (1.2–1.6 $g \cdot kg^{-1} \cdot d^{-1}$) achieves levels commensurate with activity levels.
- In a similar fashion, coingestion of carbohydrate with protein has potential to favorably impact rates of muscle glycogen recovery, but this effect is most predominant when absolute daily intake of carbohydrates are not of a level that is commensurate with activity levels (7–10 $g \cdot kg^{-1} \cdot d^{-1}$).
- Available research does indicate that postexercise ingestion of protein may exert favorable outcomes, such as improvements in strength and FFM. When this research is performed in untrained or individuals with only minimal exposure to exercise training, the impact of timing is likely greater, an outcome that is more likely to do with the training status and known changes in protein metabolism.
- Consuming multiple ($\geq$3) doses of protein in intermediate sizes doses (20–25 g) throughout the day may favorably impact changes in MPS and overall changes in body mass, fat mass, and FFM.
- In combination with a heavy resistance training program (4–5 d/wk, multijoint exercises, 3–4 sets of 6–10RM loads [70–85% 1RM], and 2-minute rest between sets), elevated intakes of dietary protein (1.2–1.6 $g \cdot kg^{-1} \cdot d^{-1}$) have been clearly shown in the literature to promote greater accretion of strength and FFM.
- Modest caloric restriction (women: 1,400–1,600 calories and men: 1,800–2,000 calories) in combination with a consistent exercise program

that combines aerobic and resistance exercise (4–5 d/wk, 170–200 min/wk) is an effective long-term approach to losing body mass with a majority of this coming from fat mass.

- Modest replacement of carbohydrate with protein (carbohydrate: protein ratio of >3.5, or protein content of 30–40% of total calories) has been shown to further promote fat loss, minimize loss of FFM, and also promote improvements in glucose, insulin, triglyceride, and cholesterol levels.

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