Supplements for Strength-Power Athletes

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SUMMARY

STRENGTH-POWER ATHLETES IMPROVE EXERCISE PERFORMANCE PRIMARILY BY IMPROVING THEIR SPORT-SPECIFIC SKILLS. IN ADDITION, EXERCISE PERFORMANCE CAN BE ENHANCED BY IMPROVING STRENGTH, LEAN MUSCLE MASS, AND ANAEROBIC EXERCISE PERFORMANCE. SEVERAL SPORTS SUPPLEMENTS HAVE BEEN DOCUMENTED TO ENHANCE THESE ATTRIBUTES, INCLUDING CREATINE MONOHYDRATE, BETA-ALANINE, β-HYDROXY β-METHYLBUTYRATE, AND PROTEIN.

INTRODUCTION

There are several ways in which strength-power athletes can improve their anaerobic performance. The primary way to improve performance is via improving skills relative to their respective sports. Secondary to this, increases in muscle mass, muscular strength, muscular power, and reaction time all are correlated to improvements in exercise performance. Many sports supplements are marketed to athletes claiming to improve muscular strength, power, and body composition. The following review attempts to bring back into focus those nutritional ergogenic aids that are supported by the scientific literature to improve exercise and sports performance. In addition, all the sports supplements discussed in this article according to the cited literature appear to be safe when ingested for brief periods by healthy individuals. Four sports supplements will be reviewed in this article: creatine monohydrate, beta-alanine, β-hydroxy β-methylbutyrate (HMB), and protein (Table).

Of these 4 sports supplements, creatine has been shown to benefit the anaerobic athlete in hundreds of scientific investigations. Beta-alanine is the newest sports supplement to have been clinically investigated and which may prove beneficial to the anaerobic athlete. HMB has been reported to increase strength and lean body mass (most likely via its anticatabolic potential), but these findings have only been observed in untrained populations. Last, protein is essential to promote a positive net protein balance in conjunction with resistance exercise. For each of the sports supplements discussed, an effort is made to highlight only those studies that have been conducted on humans with the primary outcomes relating to improvements in body composition, muscular strength, muscular power, or anaerobic exercise performance.

The supplements are discussed in alphabetical order. It is important to note that while this article focuses on sports supplements, it is not the intent of the authors to convey that dietary supplements are to be the primary focus of nutrient intake. Rather, an assumption is made that the end user of this information has a sound nutritional program in place and that supplementation is by nature to be added to the athlete's existing dietary regimen.

BETA-ALANINE

BETA-ALANINE BACKGROUND

In comparison to the other clinically investigated sports supplements reviewed in this article, beta-alanine possesses the fewest clinical investigations demonstrating its effectiveness. Part of the reason for the lack of scientific inquiry is the fact that this supplement has recently been introduced, with the majority of its published articles occurring within the last 3 years (21–24,29,52,56–58,69). The main objective when supplementing with beta-alanine is to increase intramuscular concentrations of carnosine via the enzymatic control of carnosine synthase (Figure 1). Carnosine is a dipeptide comprising beta-alanine and histidine and has been shown to buffer pH (1), function as an antioxidant (4), and regulate muscle contractility by exerting effects on excitation-contraction coupling (1). Of these benefits of increasing intramuscular carnosine levels, it is its ability to buffer pH that presents the greatest potential to improve anaerobic exercise performance.

To obtain these aforementioned benefits of carnosine, it would seem logical to simply ingest supplemental carnosine. However, when consumed orally in humans, carnosine is rapidly hydrolyzed in blood plasma by the enzyme carnosinase. Independent ingestion of beta-alanine and histidine allows these 2 molecules to be transported into the skeletal muscle and be resynthesized into carnosine. It appears that beta-alanine is the amino acid that influences intramuscular carnosine levels the most (12). In fact, it has been

KEY WORDS:
sports nutrition; sports supplements; creatine; HMB; beta-alanine; protein

Table
Popular sports supplements for the strength-power athlete

Sports supplement	Primary benefit
Beta-alanine	Increases intramuscular carnosine levels
	Buffer pH (acidity)
	Improved training volume and total work during repeated bouts
	May improve high-intensity cycling performance
Creatine	Increases strength
	Muscle mass
	Improved anaerobic exercise performance
HMB	Anticatabolic
	Suppresses muscle damage
	May increase lean muscle mass and strength in untrained subjects
Protein	Increases rates of protein synthesis
	Improves net protein balance following resistance exercise
	Aids in recovery from exercise

HMB = β-hydroxy β-methylbutyrate.

demonstrated that 28 days of beta-alanine supplementation at a dosage of 4 to 6 g per day resulted in an increase of intramuscular levels of carnosine by approximately 60% (6,19).

BETA-ALANINE DOSING PROTOCOLS

As stated above, clinical trials providing beta-alanine in the context of exercise performance are few. Therefore, recommended dosages can only be based on what the majority of these trials have reported. On a total gram per day basis, beta-alanine ingestion has ranged from 2.4 to 6.4 g per day (22–24,29,52,56–58,69). In most of these trials, the total daily amount of beta-alanine ingestion was divided into 2 to 8 smaller doses, with the most common being 4 equal doses of 1.6 g per dosage (57,58,69). Due to the relatively few investigations reporting different intakes of beta-alanine, more research is needed to determine the optimal dosage of beta-alanine.

BETA-ALANINE AND EXERCISE PERFORMANCE

Relative to anaerobic exercise performance, there have been several studies that have investigated the potential benefits of beta-alanine supplementation. A practical study conducted by Hoffman et al. (23), instructed college football players to ingest 4.5 g of beta-alanine or placebo in a randomized double-blind fashion for 30 days. Beta-alanine supplementation began 3 weeks before preseason football training camp and continued for an additional 9 days during training camp. Anaerobic performance measures included a 60-second Wingate anaerobic power test and 3 line drills (200-yd shuttle runs with a 2-minute rest between sprints) assessed on day 1 of training camp. In addition, training logs (documenting resistance training volumes) and questionnaires on subjective feelings of soreness, fatigue, and practice intensity were also assessed. At the end of the 30-day investigative period, no differences were observed in the fatigue rate in the line drill but a statistical trend ($p = 0.07$) was observed for a lower fatigue rate in those subjects ingesting beta-alanine during the Wingate anaerobic power test. Significantly higher training volumes were reported for beta-alanine in the bench press exercise, and a statistical trend ($p = 0.09$) was reported for greater training volume for all resistance exercise sessions in the beta-alanine group. Last, subjective feelings of fatigue were significantly lower for the beta-alanine group than the placebo group. From this study, it appears that 30 days of beta-alanine ingestion did not significantly improve anaerobic performance but did have a positive effect on training volumes and lower subjective feelings of fatigue.

Elsewhere (29), whole body muscular strength and changes in body composition were assessed following 10 weeks of a resistance training program (4 days per week consisting of 2 upper body dominant sessions and 2 lower body dominant sessions) and beta-alanine supplementation at a dosage of 6.4 g per day. Participants included 26 healthy, male, nonresistance-trained Vietnamese students (average age of 21 years) who were not currently involved in any resistance training program. The authors reported that there were no significant differences between a beta-alanine group (ingesting 6.4 g per day) and a placebo group in whole body strength and body composition measures following 10 weeks of supplementation.

In contrast, another study (22) reported significant improvements in a high-intensity cycling capacity test following beta-alanine supplementation. Eight physically active male subjects were supplemented with beta-alanine or a placebo (in a double-blinded fashion)

$$\text{beta-alanine} + \text{L-histidine} + \text{ATP} \xleftrightarrow{\text{carnosine synthase}} \text{AMP} + \text{diphosphate} + \text{carnosine}$$

Figure 1. The synthesis of carnosine from beta-alanine and histidine.

for a total of 10 weeks. The dosage of beta-alanine started at 4 grams per day in week 1 and progressed to 6.4 grams per day by week 10. Anaerobic exercise performance was assessed by total work done on a cycle ergometer at an intensity of 110% of the subject's maximum power output (defined as the maximum power output averaged over a 60-second period, usually during the last 75 seconds of the cycling test) and was performed prior to supplementation and at the conclusion of the 10-week supplemental period. At the end of the 10-week study, it was reported that those subjects ingesting beta-alanine significantly increased muscle carnosine by 80%. No increase was seen in control subjects. In terms of the high-intensity cycling test, it was reported that the total work accomplished was significantly improved (+16%) in the beta-alanine group, with no changes in performance in the control group.

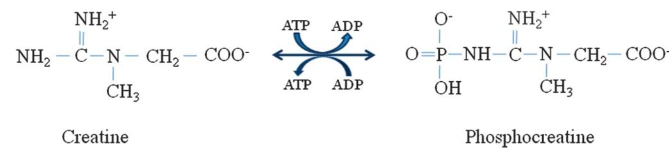

Figure 2. The synthesis of phosphocreatine from creatine and adenosine triphosphate (ATP).

CREATINE

CREATINE BACKGROUND

Creatine is currently the gold standard against which other nutritional sports supplements for strength and power athletes are compared. In fact, according to a position stand published by the International Society of Sports Nutrition, creatine monohydrate is the most effective ergogenic nutritional supplement currently available to athletes in terms of increasing high-intensity exercise capacity and lean body mass during training (6). It improves many aspects of anaerobic exercise performance, including strength, power, sprint performance, and/or work performed during multiple sets of maximal effort muscle contractions (34).

Increasing dietary availability of creatine serves to increase intramuscular total creatine and phosphocreatine concentrations (16,17,20,25) (Figure 2). Moreover, the availability of creatine and phosphocreatine plays a significant role in contributing to energy metabolism particularly during intense exercise (34). Theoretically, increasing the availability of intramuscular phosphocreatine would enhance cellular bioenergetics of the phosphagen system that is involved in high-intensity exercise performance (34).

Currently, several hundred peer-reviewed research studies have been conducted to evaluate the efficacy of creatine supplementation, and of these studies, nearly 70% have reported a significant improvement in exercise capacity (34). However, not all research reports ergogenic results from creatine supplementation (54). When improvements in exercise capacity are not observed, the likely explanation is due to the lack of an increase in skeletal muscle creatine content (6,16). Studies reporting improvements in exercise performance are often correlated to this increase (6,16).

Many forms of creatine exist (13,18,37,44,49) in the marketplace, including creatine monohydrate, creatine anhydrous, creatine phosphate, effervescent creatine, creatine ethyl ester, serum creatine, and magnesium creatine. According to published studies, the various forms of creatine seem to offer no further advantages when compared with traditional creatine monohydrate in terms of increasing strength or performance (13,18,37,44,49). Another consideration in relation to the various formulation of creatine is cost. Many of the nontraditional creatine formulations (i.e., creatine ethyl ester, effervescent creatine, etc.) contain higher price points. In contrast, creatine monohydrate powder is much more favorable from an economic perspective.

CREATINE DOSING PROTOCOLS

Several supplementation protocols have demonstrated effectiveness in increasing muscle stores of creatine (7,15). The supplementation protocol that is typically described divides the dosage pattern into 2 phases: a loading phase and a maintenance phase. A typical loading phase consists of ingesting 20 g of creatine ($\sim$0.3 $g \cdot kg^{-1} \cdot d^{-1}$) in 4 equal doses each day for approximately 5 days. Following the loading phase, a maintenance dose of 2 to 5 g daily ($\sim$0.03 $g \cdot kg^{-1} \cdot d^{-1}$) for several weeks to months is typically recommended. This type of dosing protocol (i.e., loading) results in a greater rate of intramuscular creatine saturation. An alternative to the two-phase protocol was put forth by Hultman et al. (25). This protocol suggests ingesting creatine at a dosage of 3 g per day over an extended training period of at least 4 weeks. While this protocol results in a slower rate of increase of intramuscular creatine when compared with the loading protocol, creatine levels have been shown to reach levels similar to those of the loading protocol after 4 weeks (25).

CREATINE AND EXERCISE PERFORMANCE

An abundance of evidence supports the performance-enhancing effects of creatine ingestion. For example, short-term adaptations (typically following 5 days of creatine ingestion) include increased cycling power and total work performed on both the bench press and jump squat (6,45,50,59,65,68).

Long-term adaptations (typically several weeks to several months of creatine ingestion) when combining creatine supplementation with training include increased muscle creatine and PCr concentrations, lean body mass, strength, sprint performance, power, rate of force development, and muscle diameter (6,36,62,64). Over several weeks or months of training, subjects ingesting creatine monohydrate typically gain about twice as much body mass and/or fat-free mass (i.e., an extra 2 to 4 lb of muscle mass during 4–12 weeks of training) than subjects ingesting a placebo (6,31,41). The gains in muscle mass appear to be a result of an improved ability to perform high-intensity exercise via increased PCr availability and enhanced ATP synthesis, thereby enabling an athlete to elicit a greater training stimulus and promote greater muscular hypertrophy via increased myosin heavy chain expression possibly due to an increase in myogenic regulatory factors, myogenin and MRF-4 (6,66,67).

As Kreider (34) pointed out in his review of creatine, some have criticized earlier creatine research, suggesting that although performance gains have been observed in controlled laboratory settings, it was less clear whether these changes would improve athletic performance on the field (28,39). Subsequent to these criticisms, a number of studies have attempted to evaluate the effects of creatine supplementation in high-level collegiate athletes as well as on field performance in athletes. Published results have reported that creatine supplementation improved performances in strength-power athletes who participate in football (55), ice hockey (26), and squash (48). The quantity of clinical investigations conducted demonstrating positive results from creatine supplementation leads to the conclusion that it is the most effective nutritional supplement available today for strength-power athletes.

β-HYDROXY β-METHYLBUTYRATE

β-HYDROXY β-METHYLBUTYRATE BACKGROUND

HMB is a metabolite of the branched-chain amino acid leucine and is often associated with anticatabolic potential or the ability to preserve or minimize the loss of muscle tissue. The likely mechanism of action for anticatabolic potential of HMB is its inhibition of the increased expression of the ubiquitin-proteasome pathway (53). Preventing skeletal muscle degradation seen with intense training can preserve lean body mass, which may promote greater training intensity while theoretically maintaining accrued strength gains.

Nissen et al. (40) conducted the original research study highlighting the anticatabolic potential of HMB. In their investigation, untrained subjects ingested 0, 1.5, or 3 g of HMB per day (corresponding to a relative dosage of approximately 0.02 to 0.04 $g \cdot kg^{-1} \cdot d^{-1}$) and 1 of 2 protein levels (117 or 175 g per day) and resistance trained 3 days per week for 3 weeks. Protein breakdown was assessed by measuring urinary 3-methyl-histidine (3-MH). After the first week of the resistance training and HMB supplementation protocol, urinary 3-MH was increased by 94% in the control group and by 85 and 50% in those individuals ingesting 1.5 and 3 g of HMB per day, respectively. During the second week of the investigation, 3-MH levels were still elevated by 27% in the control group but were 4 and 15% below basal levels for the 1.5 and 3 g of HMB per day groups, respectively. Interestingly, 3-MH measures at the end of the third week of resistance training were not significantly different between the groups (8,40).

Other studies have also reported the anticatabolic effect HMB and its ability to suppress muscle damage (32,63). Because this research study used untrained participants, it is important to highlight research on this population relative to protein breakdown. Phillips et al. (44) compared resistance-trained men with untrained men in relation to protein synthesis and protein breakdown following an acute bout of lower limb resistance exercise (single-leg knee flexion). Following 10 sets (8 repetitions per set) of single-leg knee flexion at 120% of the subjects' predetermined single-leg 1 repetition maximum, it was reported that protein synthesis was significantly increased in both groups. Skeletal muscle protein breakdown, however, was significantly increased only in the untrained group. Considering the perceived benefits of HMB supplementation (anticatabolic potential) to the finding reported in the Nissen study (increase in protein breakdown in the untrained group), there is justification to recommend HMB to untrained individuals or those initiating a resistance training program to prevent the increased rates of protein breakdown that are observed.

β-HYDROXY β-METHYLBUTYRATE DOSING PROTOCOLS

There is a consistent dosage of HMB ingestion in human trials investigating exercise performance, anticatabolic potential, and lean body mass changes. In nearly every published investigation relative to HMB supplementation and exercise/body composition outcomes, 3 to 6 g per day was ingested (14,27,32,35,51,63). Three g per day (often divided into several doses) is the most common dosage used in these studies.

β-HYDROXY β-METHYLBUTYRATE AND LEAN BODY MASS

Is it possible that the anticatabolic effects of HMB can lead to gains in lean body mass? Unfortunately, the published scientific literature on this topic is equivocal. In a second arm to the study conducted by Nissen et al. (40), untrained male subjects ingested 3 g of HMB (approximately 0.04 $g \cdot kg^{-1} \cdot d^{-1}$) or a placebo for 7 weeks in conjunction with resistance training 6 days per week. In this study, fat-free mass increased in the HMB-supplemented group at various times throughout the investigative period but not at the conclusion of the 7-week investigational period. On the other hand, studies that used similar training programs and doses of HMB (3 g/d) have documented that HMB ingestion increases lean body mass (14,27).

However, not all published studies agree with the findings in regard to HMB increasing lean body mass (35,42,51). Each of these studies not showing an increase on lean body mass following HMB supplementation used approximately the same amount of HMB (approximately 3 g per day) as those studies that demonstrated increases in lean body mass.

Furthermore, in HMB studies enlisting resistance-trained or highly trained athletes (35,42,51), there are consistent reports that no favorable changes are observed relative to strength and body composition (35,42,47,51). In contrast, when increases in fat-free mass are observed, they are reported when studying untrained subjects. Taking these findings into account, it appears that HMB may be beneficial (relative to increasing lean body mass) for an individual initiating a strength training program but not for athletes who are currently resistance trained.

PROTEIN

PROTEIN BACKGROUND

For the strength-power athlete, the value of supplemental protein is its role in protein synthesis and increasing lean muscle mass (in conjunction with an appropriate periodized resistance training program). Not only is protein intake required for skeletal muscle hypertrophy but protein is also needed to repair damaged cells and tissues that result from intense training. Central to the study of protein synthesis is energy intake and net protein balance. Net protein balance is equal to muscle protein synthesis minus muscle protein breakdown (2). In order for skeletal muscle hypertrophy to occur, there must be adequate energy intake (anabolic reactions are endergonic and therefore require adequate energy intake) and net protein balance must be positive (synthesis must exceed breakdown), which means that an adequate amount of protein must be ingested on a daily (and meal to meal) basis. For the strength-power athlete, 2 issues related to protein ingestion need to be addressed:

- The quantity of protein needed to enhance adaptations from training.
- The types of protein to be ingested.

RECOMMENDED PROTEIN INTAKES

Many factors need to be considered when determining an optimal amount of dietary protein for exercising individuals. These factors include protein quality, energy intake, carbohydrate intake, mode and intensity of exercise, and the timing of the protein intake (9). Protein recommendations are based on nitrogen balance assessment and amino acid tracer studies (46). The nitrogen balance technique involves quantifying the total amount of dietary protein that enters the body and the total amount of the nitrogen that is excreted (46). Nitrogen balance studies may underestimate the amount of protein required for optimal adaptations to training because these studies do not directly relate to exercise performance. Also, it is possible that protein intake above those levels deemed necessary by nitrogen balance studies may improve exercise performance by enhancing energy utilization or stimulating increases in fat-free mass in exercising individuals (38). The International Society of Sports Nutrition recommends that exercising individuals ingest protein ranging from 1.4 to 2.0 g per kg of body mass per day (9). More specifically, individuals engaging in endurance exercise should ingest levels at the lower end of this range, but those engaging in strength/power exercise should ingest levels at the upper end of this range (9).

TYPES OF PROTEINS

It is recommended that strength-power athletes obtain their protein requirements through whole foods. However, many athletes choose to obtain a portion of their protein intake from supplements such as:

- protein powders
- meal replacement drinks
- high protein energy bars

Reasons for supplementing the diet with protein supplements include convenience, simplicity, and the fact that protein supplements also have other benefits such as a longer shelf life than whole food sources in addition to being more cost effective in many cases. In addition, advances in food processing technology have allowed for the isolation of very high quality proteins from both animal and plant sources.

Two of the most popular types of proteins in supplemental form are whey and casein. Recent investigations have analyzed the serum amino acid responses to ingesting different protein types. Using amino acid tracer methodology, it was demonstrated that whey protein elicits a sharp rapid increase of plasma amino acids following ingestion, and in contrast, the consumption of casein induces a moderate prolonged increase in plasma amino acids that was sustained over a 7-hour postprandial period (3). The differences in the digestibility and absorption of these protein types may indicate that the ingestion of "slow" (casein) and "fast" (whey) proteins differentially mediates whole body protein metabolism due to their digestive properties (3). Other studies have shown similar differences in the peak plasma levels of amino acids following ingestion of whey and casein fractions (i.e., whey fractions peaking earlier than casein fractions) (5,10). Even though the digestibility and absorption of whey and casein differ, both types of protein have been reported to increase the anabolic response to an exercise stimulus (60,61).

To highlight the practical applications of protein supplementation, Kerksick et al. (30) examined the effects of whey protein supplementation on body composition and muscular strength (in addition to other variables) during 10 weeks of resistance training. Thirty-six resistance-trained men followed a 4 days per week resistance training program for 10 weeks and (in a double-blind manner) ingested 1 of 3 supplements:

- carbohydrate placebo (48 g per day)
- 40 g of whey protein plus 8 g of casein per day
- 40 g of whey protein plus 3 g of BCAAs and 5 g of glutamine per day

At the end of the 10-week intervention, significant increases in strength (measured via 1RM bench press and leg press) were observed in all groups. However, the whey plus casein group (+1.9 kg) experienced significantly greater increases in lean mass as compared with the carbohydrate placebo (0 kg) and whey-BCAA-glutamine group (−0.1 kg).

Other important considerations relative to protein intake are leucine content and protein timing. The branched-chain amino acid leucine has been shown to increase protein synthesis (11,33). Whey protein contains an abundant supply of branched-chain amino acids (including leucine), which in part explains its ability to consistently enhance protein synthesis. In relation to protein timing, a strategically planned protein intake regimen timed around a resistance training session is integral to elicit muscular hypertrophy (8,60,61). In conclusion, the International Society of Sports Nutrition recommends that when protein supplements are ingested, an attempt should be made to ensure that the protein contains both whey and casein components due to their ability to increase muscle protein accretion (9).

PRACTICAL APPLICATIONS

The strength and power athlete has distinct nutritional needs. The basis of any athlete's nutritional needs is a well-balanced diet and proper hydration. To maximize potential, however, the strength athlete should take advantage of the sport supplements that have a strong scientific basis. The first need is adequate protein intake. While there is much debate about what exactly those needs are, it is evident that to support protein synthesis and the addition of muscle mass, the strength athlete needs additional protein intake. In addition, creatine has been shown to increase strength, muscle mass, anaerobic power, and stamina. Creatine is one of the most rigorously investigated sports supplements, and the positive results associated with its use are found with little to no side effects. Two other potentially advantageous supplements are HMB and beta-alanine. HMB may spare protein by exerting anticatabolic properties. Beta-alanine may help the strength athlete primarily as a pH buffer, but more research needs to be conducted on this particular sports supplement before definitive conclusions can be made.

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