# Dietary Supplements Used in Combat Sports

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## SUMMARY

COMBAT SPORT ATHLETES IMPROVE COMPETITION PERFORMANCE PRIMARILY BY IMPROVING THEIR SPORT-SPECIFIC SKILLS. IN ADDITION, BY IMPROVING STRENGTH, POWER, POWER ENDURANCE, AEROBIC ENDURANCE, AND SPEED, COMPETITION PERFORMANCE CAN BE ENHANCED. ENHANCING RECOVERY IS ALSO A PRIMARY OBJECTIVE OF COMBAT SPORT ATHLETES. SEVERAL DIETARY SUPPLEMENTS HAVE BEEN DOCUMENTED TO ENHANCE BOTH PERFORMANCE AND RECOVERY. THESE DIETARY SUPPLEMENTS INCLUDE, BUT MAY NOT BE LIMITED TO, CREATINE MONOHYDRATE, β-ALANINE, PROTEIN, BRANCHED-CHAIN AMINO ACIDS, AND CARBOHYDRATES.

## INTRODUCTION

Combat sports, such as boxing, wrestling, judo, Brazilian jujitsu, Muay Thai kickboxing, and mixed martial arts (MMA), are dynamic sports that can challenge and potentially tax various physiological systems of the body (53). Athletes in these disciplines often seek out ways to effectively enhance athletic performance and recovery from exercise. Professional combat athletes often take a multifaceted approach to improving their success by employing professional strength and conditioning experts, nutritionists, and various professionals in the medical/allied health field.

The physical attributes, such as power, power endurance, aerobic endurance, and speed, are crucial for success in most modern day combat sports (Table 1). The consumption of certain dietary supplements, taken in conjunction with a professionally designed strength and condition program, may further optimize these attributes. To this end, the focus of this review will be on dietary supplementation that has been shown to improve exercise performance that may benefit the combat sport athlete. In addition, the potential problem of overreaching, and ultimately overtraining, are legitimate concerns to many combat sport athletes. Hence, this review will also discuss dietary supplements that have been shown to enhance recovery. In preparing this review, the authors conducted a comprehensive search for combat sport studies via a PubMed query. Search terms used in this query included "mixed martial arts," "karate," "combat sports," "boxing," "judo," and "jiu-jitsu" in conjunction with the words "dietary supplements" and "sports nutrition."

## DIETARY SUPPLEMENTS FOR ENHANCING PERFORMANCE

When considering the use of sports supplements that have the ability to enhance combat sports performance, it is helpful to delineate 2 strategies from which this can be accomplished–a chronic supplementation strategy and an acute supplementation strategy. A chronic supplementation strategy encompasses the consumption of those sports supplements that need to be ingested over a period (from several days to several weeks) before improvements in exercise performance may be realized. Sports supplements that would be classified into this domain include the following:

- Creatine monohydrate
- β-Alanine
- HMB
- Protein supplementation.

An acute supplementation strategy encompasses the consumption of those sports supplements that have the ability to improve combat sport performance when ingested in the minutes to hours before competition. Sports supplements that would be classified into this domain include:

- Caffeine
- Sodium bicarbonate.

Table 2 summarizes the purported ergogenic potential of each of these dietary supplements marketed to combat sport athletes. The intention of this review is not to focus on the mechanisms but rather on the practical applications of the performance-enhancing properties resulting from the ingestion of the dietary supplements reviewed.

## CHRONIC DIETARY SUPPLEMENTATION STRATEGY FOR ENHANCING PERFORMANCE

### *CREATINE MONOHYDRATE*

Creatine monohydrate (i.e., creatine) is the most effective dietary supplement available to combat sport athletes in terms of increasing high-intensity exercise capacity (14). Many of the physical attributes that a combat sport athlete trains to improve can be enhanced by creatine supplementation.

**KEY WORDS:**
sports nutrition; sports supplements; combat sports; mixed martial arts; creatine; β-alanine; protein

**Table 1**
**Physiological and performance variables that are critical in various combat sports**

| Sport | Aerobic endurance | Anaerobic power | Muscular endurance | Muscular strength | Muscular power | Isometric strength | Grip strength | Speed | Body composition |
|---|---|---|---|---|---|---|---|---|---|
| Wrestling | X | X | X | X | X | X | X | X | X |
| Judo | X | X | X | X | X | X | X | X | X |
| Muay Thai kickboxing | X | X | X | | X | | | X | X |
| Karate/Tae Kwon Do | X | X | X | | X | | | X | X |
| Boxing | X | X | X | | X | | | X | X |
| Brazilian jujitsu/ submission grappling | X | X | X | X | X | X | X | X | X |
| Mixed martial arts | X | X | X | X | X | X | X | X | X |

"X" indicates that the specific physiological/performance variable is critical to the athlete's success competing in that particular sport.

Specifically, combat sport athletes train to enhance strength, power, and lean muscle mass. A vast amount of scientific literature has demonstrated that creatine amplifies the training-induced adaptations to these specific skills and features (11,27,39,50,52,85).

Surprisingly, with the vast amount of creatine research existing in strength-power–trained and resistance-trained athletes, there are very few studies investigating the use of creatine in combat sport athletes. A recent investigation aimed to determine the effects of 2 weeks of creatine monohydrate supplementation on several variables, the most practical assessment being a 30-second Wingate cycle ergometer test for the upper extremities in judo athletes (62). This test is able to measure the power output of the arms during an "all-out" effort. Judo athletes were divided into 2 groups, a creatine group and a placebo group. During the first week of the study (the loading phase), judo athletes in the creatine group were given 4 doses per day of approximately 5.5 g of creatine (approximately 22 g of creatine monohydrate per day) dissolved in 20 g of a dextrose solution. During the second week (the maintenance phase), subjects were given 1 dose of approximately 5.5 g of creatine dissolved in 20 g of dextrose. Judo athletes in the placebo group followed the same protocol but were only given a dextrose solution. Before and after the 2-week supplementation protocol, the 30-second Wingate cycle ergometer test for the upper extremities was conducted.

The creatine group experienced a significant increase in peak power (12% improvement) and mean power (10.8% improvement). These improvements were nearly 3 and 2 times greater than the placebo group for peak power (4.4% improvement) and mean power (5% improvement), respectively. The findings of this study can theoretically be extrapolated to both striking and grappling combat sports. This aforementioned Wingate test for the upper extremities can indirectly be related to the force production and metabolic demands of an athlete attempting to perform various standing upper-body grappling techniques (i.e., pummeling, clinches, tie-ups, etc.). Similarly, this

**Table 2**
**Ergogenic potential of dietary supplements marketed to combat sport athletes**

| Dietary supplement | Potential benefit to the combat sport athletes |
|---|---|
| Creatine monohydrate* | Increases strength, high-intensity exercise capacity, upper-body and lower-body power production. |
| β-Alanine | Increases high-intensity exercise capacity. |
| HMB* | Increases strength in a non-trained individual. Improvements in strength not observed in resistance-trained individuals. |
| Protein* | Increases strength. |
| Caffeine | May improve reaction time and power production in trained athletes. |
| Sodium bicarbonate | Improves short-duration, high-intensity exercise performance. |

*In conjunction with a proper resistance training program.

test may also be an indirect indicator of the demands of combat an athlete may face when engaged in a flurry of repeated strikes (i.e., rapid combination of punches and elbows) with a resisting opponent.

Although several dosing protocols exist, the most popular creatine supplementation protocol divides the dosage pattern into 2 phases: a loading phase and a maintenance phase. This type of protocol was used in the aforementioned study conducted in Judo athletes (62). A typical loading phase consists of ingesting 20 g of creatine (approximately 0.3 g/kg per day) in 4 equal doses each day for approximately 5 days. After the loading phase, a maintenance dose of 2–5 g daily (approximately 0.03 g/kg per day) for several weeks to months is typically recommended (14). One area of potential concern for the combat sport athlete supplementing with creatine monohydrate is weight gain. Creatine supplementation during training is typically associated with a 0.5–2.0 kg greater increase in body mass and/or fat free mass (50). If a combat sport athlete is near the threshold of a particular weight class, a consideration of this potential weight gain needs to be considered.

## β-ALANINE

Athletes who supplement with β-alanine do so with the intention of increasing intramuscular carnosine levels. Carnosine is a dipeptide composed of the amino acids histidine and β-alanine. Carnosine is found in high concentration in skeletal muscle, primarily type II muscle fibers, which are the fast-twitch muscle fibers used during explosive movements, such as takedown attempts, throws, sprawls, and various strikes. Carnosine contributes to buffering $H^+$ concentrations (resulting from the production of lactic acid) during high-intensity activities. For this reason, carnosine is believed to be one of the primary muscle-buffering substances available in skeletal muscle (5,87). When ingested, carnosine is rapidly degraded into β-alanine and histidine, meaning that ingesting supplemental carnosine does not increase skeletal muscle carnosine levels. However, it has been demonstrated that β-alanine supplementation does increase intramuscular carnosine levels (21). Specifically, it has been reported that 28 days of β-alanine supplementation at a dosage of 4–6.4 g per day increases intramuscular carnosine levels by approximately 60% (28).

β-Alanine has been studied for its effects on strength, aerobic power, and high-intensity short-term exercises interspersed by short recovery intervals. In contrast to creatine, β-alanine does not seem to improve maximal strength (5,29,30,47). Similarly, aerobic power does not appear to be improved with β-alanine supplementation (5,30,47). Even though aerobic power is not improved, there is some data supporting that anaerobic threshold is improved with β-alanine supplementation (5,76,91). Practically, improving anaerobic threshold (as measured by the lactate and ventilatory thresholds) means that endurance activities can be performed at relatively higher intensities for longer periods. Thus, β-alanine supplementation may improve high-intensity aerobic performance that combat athletes routinely engage in during conditioning for upcoming competitions or during the actual competition itself.

Artioli et al. (5) published a comprehensive review on β-alanine supplementation and its effects on exercise performance. In addition to other performance aspects, this review focused on the effects that β-alanine supplementation exerts on high-intensity performance, which has the greatest application to combat sport athletes. The authors summarized the effects of β-alanine supplementation on high-intensity performance by stating, "… beta-alanine supplementation is capable of improving performance in exercises resulting in an extreme intramuscular acidotic environment, such as multiple bouts of high-intensity exercises lasting more than 60 seconds, and single bouts undertaken when fatigue is already present. High-intensity exercises with a lower level of acidosis are unlikely to benefit from beta-alanine supplementation (5)." Professional mixed martial artists, for example, may experience multiple bouts of high-intensity exercises lasting more than 60 seconds regularly in a fight. A professional MMA bout is generally 3–5 rounds in length with each round lasting 5 minutes. Each round is composed of many dynamic high-intensity bouts interspersed with short active recovery periods (53). In MMA, a combatant, for example, might perform a series of strikes to get close to an opponent and then may begin a series of standing grappling techniques. At this point, the athletes often joggle for position and the better grappler may ultimately takedown their opponent. Once on the ground, the athletes will continue to struggle until a dominant position is established. At this point, the dominant athletes may actively recover by stabilizing the top position on a fighter who is trapped underneath him. Thus, a fighter may experience several (>60) high-intensity bursts involving both striking and grappling (hence the name mixed martial arts) and then slow the pace down to recover. This cycle may get repeated numerous times throughout a competitive fight, particularly a full 5 round fight. As a result, β-alanine supplementation may be a benefit for certain combat athletes such as mixed martial artists.

In the published literature, β-alanine ingestion has ranged from 2.4 to 6.4 g per day (26,28,32,47,77). In many β-alanine trials, the total daily amount of β-alanine ingestion was divided into 2–4 smaller doses, with the most common being 2 or 4 equal doses of approximately 1.6 or 3.2 g per dosage supplying approximately 3.2 or 6.4 g per day (73,75,76,91). The reason for the smaller dosing strategies is to prevent the only known adverse effect of β-alanine supplementation, which is the symptom of paresthesia (tingling, pricking, or numbness of a person's skin) (5). Symptoms of paresthesia are triggered by a high and acute single dose and disappear within approximately 1 hour after the ingestion (5,26).

### β-HYDROXY-β-METHYLBUTYRATE

β-Hydroxy-β-methylbutyrate (HMB) is a metabolite of the branched-chain amino acid (BCAA) leucine and has been shown to play a role in the regulation of protein breakdown in the body. Specifically, HMB helps inhibit proteolysis, which is the natural process of breaking down muscle that occurs especially after high-intensity activity (88). Because of its anticatabolic potential, HMB is promoted to preserve or minimize the loss of muscle tissue in catabolic situations (such as resistance exercise or high-intensity training).

β-Hydroxy-β-methylbutyrate supplementation has been studied in both resistance-trained and untrained populations in terms of its effects on muscular strength and markers of muscle breakdown (i.e., creatine kinase, 3-methylhistidine, and lactate dehydrogenase) (23,49,59,84). Markers of muscle breakdown have been suppressed in conjunction with resistance exercise in untrained populations (23,84), but this observation has not been consistently reported in resistance-trained populations (31,51). Unfortunately, there are no studies investigating the use of HMB supplementation in combat sport athletes.

Irrespective of suppressing muscle damage, the practical issue that needs to be addressed for the combat sport athlete is to determine if such suppression of muscle breakdown leads to an enhancement of muscular strength. At first glance, the data on this aspect of HMB supplementation appear to be contradictory with some investigations reporting gains in muscular strength (44,59,61) and other studies not demonstrating muscular strength enhancement (23,51,60,63,72). To help explain this discrepancy, some researchers hypothesized that HMB appears to enhance strength in previously untrained (nonresistance trained) individuals, but its ability to enhance strength in resistance-trained individuals is less clear (71). To lend some credibility to this position, HMB supplementation has consistently improved strength in previously untrained individuals when ingested in conjunction with a resistance training program (44,59,61). However, in resistance and highly trained individuals, HMB supplementation has been shown to enhance strength in conjunction with a resistance training program in some investigations (81) but not others (23,51,60,63,72). In nearly every published investigation relative to HMB supplementation, 3–6 g per day was ingested (14). Three grams per day (often divided into several doses) is the most common dosage used in published studies (14).

Based on the available data, a beginning combat sport athlete engaging in training and a strength and conditioning program for the first time (or after a layoff) may benefit from HMB supplementation. However, after training for several months, the benefits of HMB supplementation in terms of enhancing strength are likely of no benefit for the combat sports athlete.

### PROTEIN

Sports nutrition research has demonstrated that competitive athletes and physically active individuals require higher levels of protein intake than the current RDA (recommended daily allowance) (0.8 g of protein per kilogram of body mass per day) (55,79). In fact, 3 academic organizations that cater to active and athletic populations advocate ingesting protein at levels greater than the RDA (refer to Table 3).

In addition to traditional combat sport training, many combat sport athletes cross-train by following strenuous conditioning and resistance training programs to increase endurance, muscular strength, and power. This type of training and physical activity stimulates cellular processes, such as transcription and translation (processes which are responsible for skeletal muscle protein accretion) (12). The protein intakes recommended by the aforementioned academic organizations helps to ensure that there is adequate substrate (i.e., amino acids) to adapt to these training-initiated stimuli. If the adaptive responses are adequate, a positive net protein balance is achieved, and ultimately skeletal muscle is gained. With appropriate skill training, it is anticipated that the increases in skeletal muscle protein are translated into functional combat sport–specific strength improvements, including upper-body striking force, kicking power, and grappling.

In a study that investigated the nutrient intakes of highly competitive collegiate karate players, it was reported that the protein intake was 1.38 g/kg per day for men and 1.17 g/kg per day for women (80). These levels are at the lower end of the ranges recommended by the American College of Sports Medicine, the National Strength and Conditioning Association, and the International Society of Sports Nutrition (1,13,65) but are still greater than current RDA recommended intakes. To obtain the recommended protein intakes, athletes commonly ingest protein supplements. In a survey that examined the dietary supplement and ergogenic aid consumption of judo athletes, it was reported that the most frequently used dietary supplement and nutritional ergogenic aids were proteins, with 85.9% of the judo

**Table 3**
**Recommended protein intakes**

| Academic organization | Recommended protein intake |
|---|---|
| American College of Sports Medicine (1) | 1.2 to 1.7 g/kg per day |
| International Society of Sports Nutrition (13) | 1.4 to 2.0 g/kg per day |
| National Strength and Conditioning Association (65) | 1.5 to 2.0 g/kg per day |

athletes surveyed reporting that they consumed protein supplements (90). The most popular protein supplements are whey protein, casein protein, and soy protein. Each of these protein sources is rich in essential amino acids. In addition, these protein supplement sources have been shown to be effective at improving muscular strength in conjunction with a resistance training program (15,18,86,89). In relation to soy protein supplementation, Laskowski et al. (54) examined the effects of a normal diet with supplemental soy protein (0.5 g/kg per day) on aerobic and anaerobic performance in judo athletes over a 4-week period. At the end of the 4-week intervention, it was reported that maximal oxygen uptake and maximal power output (via a Wingate test) performance was higher in the protein-supplemented group as compared with the control group.

In conclusion, a protein intake of approximately 1.4–2.0 g/kg per day is recommended for combat sport athletes (13). If this amount of protein cannot be ingested using whole foods, then protein supplements are an effective alternative.

## ACUTE DIETARY SUPPLEMENTATION STRATEGY FOR ENHANCING PERFORMANCE

Unlike those dietary supplements that need to be ingested for several days (or several months) to realize performance-enhancing effects, some dietary supplements are short acting in nature. When ingested in the minutes or hours before training or competition, some dietary supplements may exert a performance-enhancing effect for the combat sport athlete. Two dietary supplements that may improve combat sport performance are caffeine and sodium bicarbonate.

### *CAFFEINE*

Although caffeine ingestion has minimal effects on maximal strength (19), the potential benefits of caffeine ingestion for combat sport athletes are 2-fold—improvements in reaction time and power production. Relative to these attributes (reaction time and power production), the data are inconclusive in terms of caffeine's performance-enhancing effectiveness. Similar to other dietary supplements discussed in this review (HMB and β-alanine), investigations using combat sport athletes and caffeine as an intervention and measuring changes in exercise performance are lacking. Despite the lack of scientific support linking caffeine supplementation to combat sport performance, caffeine is a frequently used dietary supplement for judo athletes (90). Specifically, 50% of judo athletes surveyed admitted to supplementing with caffeine (90).

Studies conducted over several decades have been limited to caffeine's effect on reaction time involving reaction to stimuli using simple hand movements and have yielded positive results (22,42,57). Although these outcomes appear to be important for combat sport athletes, caffeine ingestion has not been studied in terms of its effects on improving sports-specific reaction time or in ways that can be adequately extrapolated to combat sport athletes. Another area related to reaction time is agility. Agility is defined as the ability to explosively break, change direction, and accelerate again and is a skill that involves speed and reaction time (57). Two studies investigating the effects of caffeine on agility have been conducted, and the results are conflicting (19).

In the first of these studies, investigators examined agility by having rugby players perform 3 agility sprints (22, 33, and 31 m) performed in a zigzag pattern. Caffeine (ingested at a dose of 6 mg of caffeine per kg of body mass) improved overall mean agility sprint performance for all 3 sprints by approximately 2% as compared with a placebo. However, it was not reported if this improvement was significant (19,78). In the other investigation, the researchers gave healthy, untrained, male subjects 6 mg of caffeine per kilogram of body mass and instructed them to perform a proagility test (also known as the 20-yard shuttle). The investigators failed to find a significant difference between caffeine and placebo for the proagility test (19,57).

In a comprehensive review attempting to explain the different findings from these 2 studies, Davis and Green (19) stated, "Although both studies incorporated a double-blind, crossover design, Stuart et al. (78) used trained subjects (rugby players) where Lorino et al. (57) used untrained subjects who were unaccustomed to the pro-agility test. Thus, untrained subjects not commonly performing agility work on a regular basis could have negated a potential ergogenic effect (19)."

When the effects of caffeine ingestion are studied in terms of power performance (i.e., peak power output during a Wingate test), a similar outcome that may be explained by the training status of the participants is also evident. For example, several studies have shown that caffeine ingestion does not improve power performance (16, 25,33), but those studies used recreational athletes. With competitive swimmers, caffeine ingestion (250 mg) was shown to improve sprint times during repeated 100-m sprints by an average of 3% (17,33). When summarizing the studies on caffeine ingestion and power performance, Hoffman and Stout (33) stated that if there is any performance benefit, it likely occurs in the trained athlete.

In conclusion, it appears as if caffeine ingestion may offer little benefit to the combat sports athlete. If caffeine does exert a performance-enhancing benefit, it is likely to occur in a highly trained and experienced combat sports athlete. Because plasma levels peak approximately 60 minutes after ingestion, ingesting caffeine about an hour before competition or intense training is sufficient. In terms of dose, the International Society of Sports Nutrition states that caffeine is effective for enhancing sport performance in trained athletes when consumed in low-to-moderate doses (approximately 3–6 mg/kg) (24).

### *SODIUM BICARBONATE*

Sodium bicarbonate is an antacid (alkalizing agent) used to enhance blood-buffering capacity. Vigorous exercise causes an increase in lactic acid production, which is responsible for lowering the pH of the blood and cytoplasm of skeletal muscle. Sodium bicarbonate helps to prevent this lowering of pH and is the reason that sodium bicarbonate is classified as a buffering agent. The effectiveness of sodium bicarbonate supplementation is debated in the scientific literature. If sodium bicarbonate supplementation is effective, it would likely be during exercise that demands either a prolonged high-intensity effort (e.g., greater than 100% peak power output for a minimum of 2 minutes) or one that consists of multiple high-intensity bouts separated by minimal recovery time.

Two studies investigating the effectiveness of sodium bicarbonate have been conducted in combat sport athletes. One of these studies was conducted using boxers as participants (70) and the other used judo athletes (although this study has only been published in abstract form) (4). Following is a summary of these 2 studies.

Nine judo competitors performed 3 series of a specialized judo fitness test with a recovery time of 5 minutes between each series (4). Each competitor ingested 0.3 g/kg of sodium bicarbonate or a placebo 2 hours before performing these specialized tests. After the intervention, it was reported that the judo competitors performed significantly better on the specialized judo fitness test. Furthermore, the lactate levels of the judo competitors were significantly higher after ingesting the sodium bicarbonate as compared with the placebo ingestion, indicating that the sodium bicarbonate buffered the associated decrease in pH. In the other study (70), 10 amateur boxers participated in 2 competitive sparring bouts. The sparring bouts consisted of four 3-minute rounds, each separated by a 1-minute seated recovery. Approximately 90 minutes before the sparring bouts, each boxer ingested 0.3 g/kg of sodium bicarbonate or a placebo in a randomized and counterbalanced fashion. This level of sodium bicarbonate supplementation resulted in a significant improvement in punch efficacy (successful punches thrown and landed). This finding is very applicable to combat sport athletes whose success depends in part upon their ability to punch/strike.

In summary of sodium bicarbonate supplementation, Hoffman and Stout (33) stated that it appears that sodium bicarbonate supplementation (at a dose of 0.3–0.49 g/kg) improves short-duration, high-intensity exercise performance and training. However, doses at this amount have been associated with unpleasant side effects such as diarrhea, nausea, and vomiting (33). When doses are lowered to eliminate these side effects, exercise performance is not improved (33). It is recommended that combat sport athletes wishing to supplement with sodium bicarbonate do so during practice and that dosages, effects on performance, and side effects be closely monitored. If, after experimentation during practice bouts, it is realized that there is a performance enhancement with no side effects, supplementation with sodium bicarbonate as a precompetition aid can be used.

## SUPPLEMENTS FOR ENHANCING RECOVERY

One area that is critically important to combat athletes is the ability to effectively recover from exercise. Recovery from exercise can encompass many physiological and psychological variables. However, the focus of this section will be dietary supplements that can positively affect the following 3 areas of physiological recovery:

- Replenishing muscle glycogen after exercise
- Enhancing protein synthesis after exercise
- Reducing muscle soreness. (Adequate hydration [rehydration] is also crucial to recovery. This topic will be covered in another article in this issue.)

Sufficient levels of skeletal muscle glycogen are required to support optimal exercise performance during both aerobic and anaerobic exercise (6,7,20,37,38,40). Because of the fact that combat athletes need to train their fight-specific skills as well as participate in strength and conditioning programs, it is not uncommon for these athletes to train more than 1 time per day. As a result, athletes may significantly decrease their glycogen stores between workouts, thus effecting their subsequent training session. It has been established that both aerobic and resistance exercise can deplete muscle glycogen (36,43,66,67). When muscle glycogen becomes depleted, it can promote an increased rate of adenine nucleotide loss, muscle phosphocreatine degradation, and ultimately fatigue (10,74). Thus, if an athlete is in a muscle glycogen depleted state before initiating an exercise bout, exercise performance will most likely suffer. As a result, the ability to replenish muscle glycogen is crucial.

Research has demonstrated that when carbohydrate is administered after exhaustive aerobic exercise, glycogen synthesis rates in muscle are significantly increased (38,83). In his review discussing existing glycogen resynthesis research (34), Dr John Ivy, a well-respected carbohydrate researcher, has suggested that individuals should consume in excess of 1.0 g/kg body weight of carbohydrate immediately after competition or training. Additionally, consuming carbohydrate every 2 hours after exercise will promote a rapid rate of glycogen storage up to 6 hours after exercise (34). However, it should be noted that if a combat athlete is not training multiple times a day, then the need for rapid replenishment is not as paramount. It has been reported that an individual can replenish muscle glycogen within 24 hours if they consume approximately 8 g of carbohydrate per kilogram of body mass per day and the extent of initial muscle glycogen depletion is not too excessive (46,48). Whether the addition of protein can enhance glycogen resynthesis above that of adequate carbohydrate ingestion taken alone is still debated. However, the International Society of Sport Nutrition's position stand on nutrient timing states that adding 0.2–0.5 g/kg per day of protein to carbohydrate (at an approximate ratio of 3–4:1 carbohydrate to protein) may further increase glycogen resynthesis (48). Ultimately, it is wise for the combat athlete to consume a postexercise meal that contains both carbohydrate and protein not only to promote glycogen resynthesis but also to provide the needed substrate to enhance protein synthesis and muscle tissue repair (35).

Enhancing protein synthesis after exercise is considered a vital aspect of recovery. Research has demonstrated that 40 g of essential amino acids can effectively stimulate protein synthesis after resistance exercise as effectively as 40 g of mixed amino acids (i.e., containing 21.4 g of essential and 18.6 g of nonessential amino acids) (82). In other words, to simply stimulate protein synthesis, it was shown that only essential amino acids are needed. Other research reported that after resistance exercise, as little as 6 g of essential amino acids taken in conjunction with 35 g of carbohydrate (i.e., sucrose) effectively stimulated protein synthesis (64). Subsequent studies revealed that 6 g of essential amino acids even without carbohydrate can still effectively stimulate protein synthesis (9). Table 4 lists the essential and nonessential amino acids.

**Table 4**
**Amino acid classification**

| Essential amino acids | Nonessential amino acids |
|---|---|
| Isoleucine* | Alanine |
| Leucine* | Asparagine |
| Lysine | Aspartic acid |
| Methionine | Cysteine |
| Phenylalanine | Glutamic acid |
| Threonine | Glutamine |
| Tryptophan | Glycine |
| Valine* | Proline |
| | Serine |
| | Tyrosine |
| | Arginine |
| | Histidine |

*BCAAs.

Of the essential amino acids, the BCAAs (i.e., valine, isoleucine, and leucine) and in particular leucine may be the most important in regard to either decreasing protein degradation or stimulating protein synthesis (2,8,56,58). Branched-chain amino acids can be consumed via whole foods that are rich in protein but can also be ingested in supplemental form. Branched-chain amino acids may be advantageous to consume for combat athletes looking to enhance recovery from exercise for 2 primary reasons. First, the BCAAs appear to have anabolic effects by activating various enzymes involved with translation initiation (a vital step in the regulation of protein synthesis) in skeletal muscle at rest (3,56) and after resistance exercise (3,45). Second, recent research indicates that consuming BCAAs after resistance exercise may enhance recovery by improving an individual's perception of muscle soreness and/or muscle damage. Specifically, the ingestion of BCAAs taken before and 3 times after exercise has been shown to significantly decrease muscle soreness after eccentric resistance exercise in untrained men (41). Shimomura et al. (69) reported that muscle soreness after squat exercise in untrained women was improved in individuals who consumed BCAAs (100 mg/kg body weight) before exercise as opposed to a placebo. In this same study it was reported that the females ingesting the placebo produced less leg-muscle force during maximal voluntary isometric contractions two days after the squat workout. In contrast, those subjects in the BCAA group did not have as great of a decrease in their leg muscle force generated during the maximal voluntary isometric contractions (69). Thus, the individuals who consumed BCAAs before exercise did not feel as sore and were isometrically stronger 2 days after the resistance exercise than those in the placebo group. Another study conducted at the College of Charleston examined the effects of the daily ingestion of BCAAs or placebo in conjunction with a high-intensity total-body resistance training program on various blood markers of recovery (68). The men in the BCAA group had significantly higher levels of testosterone, as well as lower levels of cortisol and creatine kinase, both during and after resistance training (68). Taking these aforementioned studies into account, it appears that the consumption of BCAAs for combat athletes may be advisable to stimulate protein synthesis, decrease muscle damage, and decrease the perception of muscle soreness.

## SUMMARY

Very few publications exist in which combat sport–specific exercise performance was measured in response to dietary supplementation. Therefore, combat sport athletes and those who train them are reliant upon the broader base of the sports nutrition literature and must extrapolate those findings to their specific disciplines. Within this context, it appears that creatine monohydrate, β-alanine, and protein supplementation (ingested for several days to several weeks) are worthy of consideration for the combat sport athlete in terms of improving exercise performance that is specific to their craft. Furthermore, sodium bicarbonate supplementation (ingested 1–2 hours before highly intense activity) may also improve sport-specific exercise performance. However, side effects are common with sodium bicarbonate supplementation, so care must be taken.

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