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Creatine and Beta-Alanine Supplementation for Increased Anaerobic Performance in Sprinting, Jumping, and Throwing Track and Field Athletes

Short Review

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Abstract
Track and field athletes involved in sprinting, jumping, and throwing events are one of the largest groups utilizing both speed and power. As a result, this group of athletes could potentially benefit from creatine and beta-alanine supplementation. Short duration, high intensity exercise utilizes the immediate energy adenosine triphosphate (ATP)-phosphocreatine (PCr) system and will result in an accumulation of ADP, Pi, and H^+ and contribute to muscle fatigue. For activities between ten second and two minutes, creatine in the cells can reduce pH changes by using hydrogen ions in the creatine kinase reaction and when phosphorylating ADP to ATP Theoretically, an increase in an immediate energy systems ability to act and recovery would increase an athlete's capability to anaerobically exercise. Creatine supplementation can be used to increase intramuscular PCr levels. Beta-alanine bonds with histidine within muscle to create carnosine, a cytoplasmic dipeptide that operates as an intracellular pH buffer. Therefore, increasing beta-alanine through diet or supplementation is a way of increasing intramuscular cell buffering capacity. The ability to buffer pH is needed in athletes who perform activities that results in the acidosis of muscle Research on how these two supplements affect track and field athletes are limited. However, much research has been done to show creatine and beta-alanine's effects on muscle strength and power for track and field events such as sprinting, jumping, and throwing. The purpose of this review is to discuss research studies involving creatine and beta-alanine supplementation and the implications for potential ergogenic effects in specific track and field events involving sprinting, jumping, and throwing.

Key words: muscle performance, strength, power, exercise

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Introduction

The use of nutritional supplements by athletes worldwide is continually growing due to their alleged ergogenic benefits. The National Collegiate Athletic Association (NCAA), International Association of Athletics Federations (IAAF), and other athletic foundations ban certain types of supplements due to chemical and hormonal substances that may provide unfair advantages to the athlete. However, nutritional supplements such as whey protein, branched chain amino acids (BCAAs), creatine, beta-alanine, and caffeine are all legal. A major concern among collegiate athletes in the United States is the improper use and dosage of nutritional supplements. NCAA Division 1 Bylaw 16.5.2g places creatine on a "non-permissible" list of supplements making it so that colleges cannot provide their athletes with creatine.[1] It is up to an athlete to supplement creatine on their own. In a survey of 258 NCAA Division 1 track and field throwers, only 26% stated their college provided nutritional supplement counseling.[1] Issues such as this among collegiate athletes cause there to be a mass ignorance of not only the dosage but the affects nutritional supplements can have on the body. Two of the most popular nutritional supplements on the market to increase anaerobic performance are creatine monohydrate and beta-alanine. Track and field athletes, particularly, are one of the largest groups utilizing both speed and power and could potentially benefit from creatine and beta-alanine supplementation. Research on how these two supplements affect track and field athletes specifically are limited. However, much research has shown creatine monohydrate and beta-alanine's effects on aspects of certain track and field events involving anaerobic power and muscle strength, such as sprinting, jumping, and throwing. The purpose of this review is to discuss research studies involving creatine and beta-alanine supplementation and the implications for potential ergogenic effects in specific track and field events involving sprinting, jumping, and throwing.

Creatine Supplementation

In a study done on elite Finnish athletes, the most common supplement among speed and power athletes was creatine.[2] This is because short duration, high-intensity exercise utilizes the immediate energy adenosine triphosphate (ATP)-phosphocreatine (PCr) system. For activities between ten seconds and two minutes, intramuscular creatine can reduce pH changes by using hydrogen ions (H^+) in the creatine kinase reaction and when phosphorylating ADP to ATP.[3] For activities less than 10 seconds, ATP production is mainly due to rapid re-phosphorylation of ADP to ATP by the creatine kinase-catalyzed reaction. Studies agree that creatine supplementation increases the amount of intramuscular creatine.[4] The effects of this increase of creatine on performance in studies has varied. Theoretically, an increase in the immediate energy system's activity and ability to recover would increase an athlete's capability to anaerobically exercise. One would have to understand dosages and the phases of creatine supplementation to induce the proper effects. Creatine supplementation is broken down into two phases; the loading phase and maintenance phase. The purpose of the loading phase is to saturate the muscles with creatine and the purpose of the maintenance phase is to maintain the saturation. According to Judge et al.[1], the recommended loading phase is for five to seven days and includes doses of about 0.3 g/kg/day, which is approximately 20-25 grams. The recommended maintenance phase is only 3-5 grams per day. Without proper dosages during the phase, one may not achieve the level of saturation needed for creatine supplementation to have any significant effects on anaerobic performance.

Creatine for Sprinters

The track and field events that encompass sprinting for a length of time that only utilizes the immediate energy systems would be the 100- and 200-meter as well as the 110- and 100-meter high hurdle races, and the 60-meter dash during indoor track. Most of these events (four out of five) are held during the outdoor track and field season and thus would contribute to the fact that the nutritional supplements used by top level/professional track and field athletes were during the World Outdoor Championships. It was found that creatine use was highest among power and sprint athletes when compared to all other track and field events.[5] A study by Kirksey et al.[6] focused on creatine monohydrate supplementation in track and field athletes. They tested sprinters, jumper, and throwers on a multitude of anaerobic tests including a 10-second maximum effort cycle ergometer ride. After six weeks of creatine monohydrate supplementation at a dosage of 0.3 g/kg/day, there were increases in average cycle peak power from 4.8% to 12.8%, cycle average power from 3.1% to 10.8%, cycle total work from 3.5% to 10.8%, and cycle initial rate of power production from 11.2% to 30.0%. The 10-second cycle ergometer ride in this study is considered comparable to a 100-meter sprint in track and field. In a more recent study, creatine monohydrate supplementation with 20 g/day for seven days increased anaerobic power output on the Wingate test when compared to placebo.[3] The Wingate anaerobic test is composed of a warm up and a maximum pedal for 30 seconds and was performed twice with seven minutes between. Relatedly, this 30 seconds of maximum effort can be compared to the 200-meter race in track and field and indicates that creatine monohydrate supplementation can increase the capacity of the body to anaerobically produce ATP and help with recovery between successive bouts of anaerobic exercise.

Other studies suggest that creatine supplementation does not increase anaerobic running capacity but rather helps increase training volume and maximum oxygen consumption (VO_2 max). For instance, Smith et al.[4] supplemented moderately-trained athletes with a product named “Game Time” consisting of 100 mg of caffeine, 1.5 g creatine [buffered creatine monohydrate (Kre-Alkalyn)], 9 g whey protein, and 1 g of branched chain amino acids for three weeks of high intensity training. Anaerobic running capacity was tested using treadmill runs to exhaustion. Compared to initial tests, supplementation increased the VO_2 max as as well as lean body mass and total training volume and was most likely an effect of increased high-intensity interval training volume. In this study, Smith et al.[4] found creatine supplementation most likely did not increase this capacity. This could be because of other ingredients in the supplement or the significantly less amount of creatine in it compared to previous studies (1.5 g per serving vs. 20 g). Therefore, the creatine may not have had a chance to saturate the muscle cells enough to impact anaerobic performance. Regardless, creatine monohydrate supplementation has been shown to increase training volume, VO_2 max, and anaerobic power output; therefore, creatine supplementation could be beneficial for track and field sprinters.

Creatine for Jumpers

Jumping is an event that can fall under both the power and sprint categories. In the high jump, long jump, triple jump, and pole vault the athlete must sprint up to their respective bar or sand pit and then use their power to jump. A study was performed that tested the impact of creatine monohydrate supplementation on countermovement vertical jump and a static vertical jump.[6] Supplementation was provided with 0.3 g/kg/day of creatine monohydrate for six weeks and and increased countermovement vertical jump height from 2.3% to 7.0% and static vertical jump from 3.1% to 6.8% was observed. However, in a more recent study performed on collegiate male volleyball players,[7] this result could not be replicated. During the loading phase, the athletes ingested 5 g creatine portions four times a day for four days, and then decreased to the maintenance phase of two 5 g two portions a day for two days, and then one 5 g portion a day for the remaining 22 days. Each athletes’ three step spike jump height as well as repeated-block jump heights for 10 sets of 10 static jumps were determined and results showed that jump height for the spike jump did not increase for the creatine supplementation group. However, the decrement of jump heights for the repeated-block jumps was of lesser percentage in creatine-supplemented players compared to the placebo. While competing in a track and field jumping event is more like a three-step spike jump in volleyball, an increase in the anaerobic ability to perform multiple jumps quickly and recover in between could be beneficial to plyometric workouts for jumping athletes.

Creatine for Throwers

One of the major components to any of the throwing events in track and field is strength and power. While technique plays an important role in events like the javelin and discus throw, overall muscular strength can have a large effect on events like the shotput, hammer, and discus throw. Creatine supplementation has been used by athletes to increase muscular strength because it delays the onset of muscular fatigue, thus increasing the amount of resistance training someone can do. Zuniga et al.[2] showed an increase in mean power in the Wingate anaerobic test due to creatine supplementation and evaluated the effects of creatine on a one repetition maximum (1RM) leg extension and bench press. Subjects were supplemented with 20 g/day of creatine for seven days and then determined their 1RM for the leg extension and bench press exercises. In between, subjects were encouraged to engage in their normal daily exercise routines, which may have skewed the results. Both the placebo and creatine supplement groups showed increases in 1RM for leg extension and bench press; however, but there was no difference between the groups.

Conversely, Ciccone et al.[8] investigated not only the effects creatine monohydrate supplementation had on strength and body composition, but also if the timing of intake (pre- or post-workout) of creatine had any differential effects. Male subjects split into groups of pre-workout or post-workout ingestion of a 5 g creatine supplement. They were given a workout regime to follow for four weeks and then tested for their body composition and 1RM bench press. Overall, fat free mass increased, fat mass and % body fat decreased, and 1RM bench press increased in both groups. However, the post-workout supplementation group exhibited greater differences in their pre and post study data. Both groups performed the exact same exercise regime and thus, the differences in final data can be attributed to creatine supplementation and its timing.

Moreover, after interviewing NCAA Division 1 throwers across the United States, Judge, et al.[1] found that 70% of males reported that creatine supplementation was beneficial in some way and that the perception of creatine being beneficial was related to a greater overall belief among them that creatine would improve stamina, muscle endurance, enhance recovery, and improve the distance they could throw. This could be a placebo affect or could be actual beneficial affects by creatine supplementation.

Beta-Alanine Supplementation

High-intensity anaerobic exercise will result in an accumulation of metabolites such as ADP, Pi, and H^+ which can have negative effects on the muscle performance due to fatigue. Carnosine, a cytoplasmic dipeptide, has a pKa side chain making it an intracellular pH buffer. The concentration of carnosine in muscles is higher within males compared to females and higher in fast twitch muscle fibers.[9] The bonding of histidine and beta-alanine creates carnosine due to the reaction catalyzed by the carnosine synthase enzyme. Therefore, increasing beta-alanine through diet or supplementation is a way of increasing intramuscular cell buffering capacity. The ability to buffer pH is needed in athletes who perform anaerobic-related activities that results in the muscle acidosis. When the glycolytic rate exceeds that of the pyruvate oxidation in cells, lactic acid will be formed. Lactic acid can be used to continue muscle contractions for a short period of time but will causes acidification of the cells due to H^+ and lactate anions.[10] Hydrogen ions have been shown to slow down the re-synthesis of phosphocreatine, thus inhibiting anaerobic systems.[11] It also has been reported that carnosine can increase the sensitivity of calcium release channels, as well as muscle fibers to that calcium, and increase vasodilation of blood vessels.[12] Therefore, for someone to maintain anaerobic exercise for a longer period of time without fatigue, carnosine is needed. Beta-alanine supplementation help synthesize carnosine and has been proposed as the rate limiting substrate for production.[11] For beta-alanine to be effective, the event or exercise must induce fatigue by a reduction in PCr along with a subsequent increase in lactic acid and H^+ within the muscles. Power events in track and field are not likely to do this; however, longer duration races such as the 400-meter, 400-meter intermediate hurdles, 600-meter (during indoor track), and the 800-meter (a middle-distance race) races would be of sufficient length to induce lactic acidosis.

Beta-alanine for Short-Distance Sprinters

Shorter-length sprints, such as 100-400 meter, may not be as positively affected by beta-alanine due to an insufficiency in lactic acidosis. Nevertheless, beta-alanine's effects on sprints and repeated-sprint workouts have still been investigated. A study provided beta-alanine at an average daily dose of 3.6 g daily to competitive 400-meter sprinters for four weeks. While sprint performance was not improved, beta-alanine supplementation was shown to significantly increase intramuscular carnosine levels.[13] Nevertheless, there is potential for beta-alanine supplementation to improve anaerobic exercise in this group of athletes.

College-aged men were placed in either a placebo or a beta-alanine supplementation group, both receiving 4 g/day for the first week and then 6 g/day the following four weeks.[11] Time to exhaustion (TTE) and VO_2 max in sprints at 115% and 140% VO_2 max were determined. Results showed a small increase in the TTE; however, there was no significant difference between placebo and supplementation groups. The authors hypothesized that the subjects may have enhanced their buffering capacity simply through training alone and that the beta-alanine dosage not have been high enough or perhaps because the TTE treadmill sprints were approximately 60 seconds, that the exercise used in the study was not of sufficient anaerobic intensity to require significant reliance on beta-alanine.

A similar study by Deminice et al.[14] provided creatine monohydrate supplementation to male athletes at a dose of 0.3 g/kg for seven days who then performed two consecutive running-based anaerobic sprint tests, which consisted of six 35-meter sprint runs at maximum speed with 10 sec rest between them. Average, maximum, and minimum power values were greater in the creatine-supplemented group compared with placebo. Likewise, a study using the "Longborough Intermittent Shuttle Test" involved a group of subjects perform a series of 11 sprints six times with a three-minute rest in between.[10] One group used a placebo and the other supplemented doses of 800 mg beta-alanine twice daily. There was no effect of beta-alanine supplementation on sprint performance as sprint times did not change between sets. Thus, short sprints, though they were repeated, may not have been enough to produce muscular fatigue to the extent that beta-alanine would be positively effective.

It is possible that sprints such as the 400-meter and 400-meter intermediate hurdles may not reduce intramuscular pH enough for beta-alanine to be effective.

On the other hand, these races may likely benefit more from supplementation of beta-alanine compared to short sprints such as the 100 and 200 meter.

Beta-Alanine for Middle-Distance Sprinters

Exercise needs to be fatigue-inducing enough for beta-alanine to have any noticeable effects on performance. Track and field races that exceed 60 seconds could potentially be candidates for improved performance for beta-alanine. The 800-meter middle-distance race requires a significant contribution from anaerobic energy systems because it is ran almost like a sprint race. Ducker et al.[12] investigated the effects that beta-alanine had on performance in the 800-meter race. Beta-alanine dosages were 80 mg/kg/day for 28 days. Compared to the control group, the beta-alanine group was faster overall in 800-meter time trials post-supplementation. The supplemented group decreased their overall run time by -3.6, their first 400-meter split by -1.24 seconds, and their second 400-meter split by -2.38 seconds. The placebo group showed no significant changes pre- and post-placebo supplementation. While the decrease in the second 400- meter split time indicates the effectiveness of beta-alanine at buffering pH, by that point in the 800-meter race, apparently fatigue had already become appreciable enough to allow for improved performance. Increased beta-alanine apparently helped create more carnosine to buffer the increased H^+ resulting from a reduction in pH and reduce the negative effects on the muscle, thus leading to an overall faster split time. Likewise, a study that supplemented subjects with 6.4 g/day of beta-alanine showed a delay in the onset of blood lactate when completing a test to exhaustion where incline steadily increased at a fixed speed of 6.0 mph.[15] This delay in the onset of blood lactate lead to increased percentage of VO_2 max, heart rate, and percent heart rate max reached before volitional fatigue. Due to the apparent ergogenic effects of this supplement, subjects supplementing with beta-alanine were able to exercise at a higher intensity than when not ingesting beta-alanine. An increase in the lactate threshold is very important for athletes in races such as the 800 meters where even workouts at 80% intensity can cause the onset of lactic acid and induce fatigue.

Discussion

Due to the high-intensity, explosive, anaerobic nature of track and field events involving sprinting, jumping, and throwing, many studies have shown both creatine monohydrate and beta-alanine supplementation to have ergogenic effects. The high-intensity efforts of these events increase the energy demand on skeletal muscle. Moreover, anaerobic exercise generates a biochemical link between energy production and mechanical work through the availability of ATP. It must be emphasized that the availability of ATP is also contingent on the ability of skeletal muscle to continually replenish ATP, either through the activity of creatine kinase or adenylate kinase (myokinase) activity.

During anaerobic exercise, glycolytic activity exceeds the muscles' ability to oxidize pyruvate; therefore, lactic acid production allows the continuation of muscle contraction. However, acidification occurs resulting in dissociation and subsequent formation of the lactate anion and H^+.[10] This process generates a reduction in intramuscular pH (ipH) and interferes with several metabolic processes including a reduction in muscle force production and the onset of fatigue.[16] Functionally, this implies that a reduction in sprint performance might be attenuated in athletes who are able to more effectively buffer reductions in iPH. The ability for sprinters, jumpers, and throwers to perform their events effectively is highly contingent on their ATP availability and H^+ buffering capacity,[17] as an increased ADP/ATP and concomitant accumulation in H^+ can detrimentally impact muscle performance. Relatedly, a disruption in the recovery of PCr, glycolytic inhibition, and disruption in muscle contraction have all been associated with a decreased ipH.[18-21]

Based on the results from studies discussed herein, creatine monohydrate and beta-alanine supplementation may have a positive impact on high-intensity, anaerobic exercise performance. However, more research needs to be done pertaining to the effects of these supplements on specific activities or events within a sport. For instance, there is research on how creatine affects vertical max and repeated jumps, but more research could be done in the realm of how creatine supplementation would affect a long jumper who must sprint and leap off one leg in competition. Additionally, more research could be done on how these two supplements could affect multi-event athletes. With heptathletes and decathletes performing seven or ten events within two days, any nutritional supplement that could help them not only perform better but recover quicker would be beneficial. There is room for vast improvement in the realm of research on specific track and field events; however, the available research with creatine monohydrate and beta-alanine supplementation suggests ergogenic effects on the training and performance sprinting, jumping, and throwing track and field athletes.

Media-Friendly Summary

Based on the information presented herein, it appears that individuals involved in short duration, high-intensity exercise, such as track and field athletes performing sprinting, jumping, and throwing events, can potentially benefit from creatine and/or beta-alanine supplementation.

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