Global Journal of Health Science; Vol. 16, No. 2; 2024
ISSN 1916-9736 E-ISSN 1916-9744
Published by Canadian Center of Science and Education

Creatine Supplements: What the Research Says about How It Can Help Healthy Athletes

Mimansa Dahal[1], Keshab Raj Dahal[2], Nawa Raj Pokhrel[3] & Durga Kutal[4]

[1] Department of Mathematics and Statistics, Binghamton University, Binghamton, New York, USA

[2] Department of Mathematics, State University of New York Cortland, Cortland, New York, USA

[3] Department of Physics and Computer Science, Xavier University of Louisiana, Louisiana, USA

[4] Department of Mathematics, Augusta University, Augusta, Georgia, USA

Correspondence: Mimansa Dahal, Department of Mathematics and Statistics, Binghamton University, 4400 Vestal Pkwy E, Binghamton, NY 13902, USA. Tel: 1-989-495-8913. E-mail: mdahal@binghamton.edu

Received: December 26, 2023 Accepted: January 15, 2024 Online Published: January 23, 2024

doi:10.5539/gjhs.v16n2p48 URL: https://doi.org/10.5539/gjhs.v16n2p48

Abstract

Creatine is a popular and widely used ergogenic dietary supplement among athletes, for which studies have consistently shown increased lean muscle mass and exercise capacity when used with short-duration, high-intensity exercise. This article provides an overview of creatine supplementation, particularly in the context of athletes, focusing on its safety, benefits, dosage, and considerations for young individuals. Research has shown that creatine supplementation may provide additional benefits including enhanced post-exercise recovery, injury prevention, and rehabilitation, as well as several potential neurological benefits that may be relevant to sports. Studies show that short- and long-term supplementation is safe and well-tolerated in healthy individuals and several patient populations.

Keywords: Creatine, physical performance, fitness, muscle strains

1. Introduction

Methyl guanidine-acetic acid, commonly named creatine, is a naturally occurring compound that is found in the human body (Wyss & Kaddurah-Daouk, 2000). The primary dietary sources of creatine include meat and fish, dietary supplements, and synthesis in the body. Creatine is particularly abundant in meat and fish. Beef, pork, and various types of fish, such as salmon and tuna, are rich sources (Burini & Cyrino, n.d.; Hall & Trojian, 2013; Jäger et al., 2011; Williams et al., 1999). Creatine has become widely used as a dietary supplement by athletes wishing to maximize performance and training gains (Burini & Cyrino, n.d.; Pittas et al., 2010). The human body is naturally capable of producing creatine. Around a half of the body's supply comes from a carnivorous diet and about half is produced in the liver, kidneys, and then delivered to the skeletal muscles for use (Cooper et al., 2012; Curt et al., 2015; Greenhaff, 1997; Williams et al., 1999).

Creatine plays a crucial role in energy production during high-intensity training and is an important factor in muscle growth and repair. Over the past few decades, creatine supplementation has become increasingly popular among athletes and fitness enthusiasts due to its potential benefits. Creatine plays a crucial role in energy production during high-intensity training and is an important factor in muscle growth and repair. Moreover, the brain is the main human organ affected in creatine-deficient patients, who show severe neurodevelopmental delay and present neurological symptoms in early infancy (Béard & Braissant, 2010; Braissant et al., 2011; Cunha et al., 2013).

The body utilizes creatine for energy during intense training. It has also been shown to have the potential benefits of improved exercise performance, aiding in recovery after intense exercise, preventing and/or reducing the severity of injury, aiding in helping athletes tolerate heavy training loads, and increasing fat-free muscle mass during training (Hall et al., 2021; Kraemer & Volek, 1999). In other words, creatine is a substance that aids the body in several ways during and after training.

One reason creatine supplementation can be beneficial to athletes is the human body only produces around 1 gram of creatine, which is not optimal. For those who train extensively in their daily lives, it is beneficial for their bodies

to be supplemented with creatine. Creatine creates energy by participating in the production of Adenosine tri-phosphate (ATP) via its integration to the creatine phosphate energy system (D'Cruz & Ribeiro, 2013). ATP is crucial because the human body is dependent on ATP for energy. Without proper ATP production levels, it is extremely difficult to have the energy needed to train. Studies have shown that creatine provides athletes with a quick burst of energy, which increases strength and improves performance (Butts et al., 2018; Sandler, 2005; Shadowen, n.d.).

Another benefit of creatine regarding energy is the fact that creatine participates in the regulation of the glycolysis (Guzun et al., 2011; Li et al., 2013). This is beneficial because fatigue during training is not uncommon. Athletes usually go through hours of training daily and it is difficult to maintain a high level of energy during the entirety of training. According to the authors (Ament & Verkerke, 2009; Antošová & & Plevkova, n.d.; D'Cruz & Ribeiro, 2013; Rahal et al., 2014), in case of the exhaustion of the organism, tissues containing the creatinine can adapt to this situation by the up-regulation of the activity of certain oxidative enzymes, which in turn may help the energy sustainability in the cells. This feature of creatine is incredibly advantageous for athletes because their bodies will be able to utilize the creatine to aid in maintaining their energy levels and prevent it from negatively impacting their performance.

Creatine also aids in recovery post-training (Antonio & Ciccone, 2013; BEMBEN et al., 2001; Wang et al., 2018). According to the authors (Bachl, 2009; Burini & Cyrino, n.d.; D'Cruz & Ribeiro, 2013; Ergen, Ülkar, & Güner, n.d.), creatine has a major role on post-exercise induced damage by slowing down the degeneration phase and accelerating the regeneration phase after high-intensive exercises. It is not uncommon for athletes to feel sore after training. An athlete can take every precaution, such as stretching and hydration, in an effort to minimize the effects on their body post-training, but there is no guarantee that they will not face exercise-induced muscle damage (EIMD). EIMD causes increased soreness, impaired muscle function, and reductions in muscle force. One way to combat EIMD is by supplementing creatine. Supplementing creatine aids the body because creatine consumption might reduce post-exercise muscle damage via mechanisms regulating mitochondrial permeability and stabilizing the sarcolemma membranes by increasing intramuscular phosphocreatine content (Howatson & Van Someren, 2008; Hunter et al., 2012; Jiaming & Rahimi, 2021; Owens et al., 2019). Phosphocreatine is a source of ATP and is also known for its regenerating purposes and is crucial in the energy shuttle system (Vulturar et al., 2021). Creatine and the increase of intramuscular phosphocreatine allows for faster regeneration, which allows athletes to recover faster. The cycle of faster recovery after training allows athletes to build up their endurance. As a result, the increase in endurance results in athletes improving their overall performance and skill level.

The data utilized by Jaiming and Rahimi (Jiaming & Rahimi, 2021) indicates that consuming creatine is better than only resting after participating in intense exercise because the benefits of creatine have been shown to relate to a decrease in muscle damage indices. Fewer incidents of muscle damage reduce the need for athletes to take a break from training due to injuries caused by muscle damage. Creatine has also been shown to improve muscle function by preventing higher muscle power loss after exercise (Cooke et al., 2009; de Salles Painelli et al., 2014; Izquierdo et al., 2002; Jiaming & Rahimi, 2021). Supplementing creatine after training aids the body in recovery by reducing the extent to which muscles are damaged. As a result, athletes can shorten the time it takes to recover, which allows them to gain strength faster. Additionally, individuals who supplement creatine experience less frequency of sports-related symptoms such as cramping, dehydration, muscle tightness, muscle strains, and total injuries than their counterparts (Cohen, 2005; PANEL, 2009; Tietze & Borchers, 2014; Walker et al., 2013; Wallimann et al., 2011).

2. Effects of Creatine Supplementation on Physical Performance

Several studies have been done on the effectiveness of creatine in sports. Chrusch et al. (2001) studied the effect of creatine supplementation combined with resistance training on muscular performance and body composition in older men. Thirty men were randomized to receive creatine supplementation. Sixteen were given 0.3 grams of creatine for each kg of body weight for 5 days (loading phase) and 0.07 grams for each kg of body weight for 11 weeks (maintenance phase). The remaining 14 men were given a placebo. The author experimented using a double-blind procedure and concluded that creatine improved strength in the lower body, and power, and increased lean muscle tissue/mass.

Kerksick et al. (2009) studied whether adding D-pinitol to creatine affects training adaptations, body composition, whole-body creatine retention, and/or blood safety markers when compared to crea-tine ingestion alone after 4 weeks of resistance training. Twenty-four resistance-trained males were randomly assigned in a double-blind manner to creatine plus pinitol (CRP) or creatine monohydrate (CR) before the be-ginning of the training. Data were analyzed by repeated measures analysis of variance (ANOVA). Creatine retention increased in both groups

(higher in CR compared to CRP) as a result of supplementation. Significant improvements in upper- and lower-body strength, lean mass, fat-free mass, and body composition occurred in both groups.

Brose et al. (Brose et al., 2003) studied to determine whether creatine supplementation would enhance the increases in strength and fat-free mass that develop during resistance exercise training in older adults. Twenty-eight healthy men and women over the age of 65 years participated in a whole-body resistance exercise program 3 days per week for 14 weeks. Study participants were randomly allocated, in a double-blind fashion, to receive either creatine or a placebo. Creatine supplementation resulted in significantly greater increases in fat-free mass, isometric knee extension strength, and total body mass.

Kreider et al. (Kreider et al., 1998) studied to determine the effects of 28 days of creatine supplementation during training on body composition, strength, sprint performance, and hematological profiles. In a double-blind and randomized manner, 25 NCAA division IA football players were matched-paired and assigned to supplement their diet with creatine versus placebo. The authors found that the total body weight, fat/bone-free mass, and the total work performed significantly increased in the group that consumed creatine. They concluded that the creatine supplement promoted greater gains in fat/bone-free mass, isotonic lifting volume, and sprint performance during intense resistance/agility training.

The purpose of the study of Ferguson & Syrotuik (Ferguson & Syrotuik, 2006) was to examine creatine supplementation coupled with resistance training on body composition and strength in women. Twenty-six women ingested creatine (n =13) or a placebo (n =13) while performing a resistance training program 4 days per week. The results indicated that creatine supplementation combined with 10 weeks of concurrent resistance training may not improve strength or lean body mass greater than training only. These findings may have been a result of nonresponses due to gender differences or a varying biological potential to uptake creatine within the muscle.

The purpose of the study of Becque (Becque et al., 2000) was to examine the effects of creatine supplementation during a periodized program of arm flexor strength training on arm flexor 1RM, upper arm muscle area, and body composition. Twenty-three male volunteers with at least 1 year of weight training experience were assigned in a double-blind fashion to two groups. The first half was given creatine, and the rest were given the placebo. The authors concluded that creatine supplementation during arm flexor strength training leads to greater increases in arm flexor muscular strength, upper arm muscle area, and fat-free mass.

To determine the effects of creatine supplementation during short-term resistance training overreaching on performance, body composition, and resting hormone concentrations, Volek et al. (Volek et al., 2004) randomly assigned creatine supplementation for 9 men and placebo for 8 men while performing 6 weeks of resistance exercise program. The author concluded that the creatine supplementation appears to be effective for maintaining muscular performance during the initial phase of high-volume resistance training overreaching that otherwise results in small performance decrements.

To determine the effects of creatine supplementation on maximal strength, muscle power production during repetitive high-power-output exercise bouts, repeated running sprints, and endurance in handball players. Izquierdo et al. (2002) randomly assigned creatine for 9 or placebo for 10 out of 19 trained male handball players in a double-blind fashion. They concluded that the short-term creatine supplementation leads to significant improvements in lower-body maximal strength, maximal repetitive upper- and lower-body high-power exercise bouts, and total repetitions performed to fatigue, as well as enhanced repeated sprint performance and attenuated decline in jumping ability in highly trained handball players.

Mujika et al. (2000) examined the effects of creatine supplementation on intermittent high-intensity exercise activities specific to competitive soccer. Seventeen highly trained male soccer players performed a countermovement jump test, a repeated sprint test, an intermittent endurance test, and a recovery countermovement jump test consisting of three jumps. After the initial testing session, players were evenly and randomly included in a creatine or a placebo group using a double-blind research design. The authors concluded that acute creatine supplementation favorably affected repeated sprint performance and limited the decay in jumping ability after an intermittent endurance test in highly trained soccer players. Intermittent endurance performance was not affected by creatine.

Young healthy male subjects were randomized to receive either creatine and glucose (CR-CHO) or protein and glucose (PRO-CHO) using double-blinded allocation. There were 11 males in the CR-CHO group and 8 males in the PRO-CHO group. Participants performed 8 weeks of whole-body split-routine straight-set weight training. Measurements, pre- and post-training were made of fat-free mass, total body mass, muscle fiber area, isokinetic knee extension strength, and 1 repetition maximal strength for 16 weight training exercises. After conducting this

study, Tarnopolsky et al. (2001) concluded that postexercise supplementation with PRO-CHO resulted in similar increases in strength after a resistance exercise training program as compared with CR-CHO. However, the greater gains in total mass for the CR-CHO group may have implications for sport-specific performance.

Syrotuik et al. (2001) investigated the effect of creatine supplementation on performance and training volume in rowers. Twenty-two rowers were trained with continuous and interval rowing and resistance training 4 and 2 days/week, respectively, for 6 weeks. Their study concluded that the creatine supplementation does not increase performance or training volume over a placebo condition in rowers that perform a combined high-intensity rowing and strength program.

Table 1. Creatine supplementation performance summary

Study	**Findings**
Chrusch et al. (2001)	Improved strength in the lower body, power, and an increase in lean muscle tissue.
Kerksick et al. (2009)	Improvement in strength and body composition.
Brose et al. (2003)	Increase in isometric muscle strength. Increase in total mass and fat-free mass
Kreider et al. (1998)	A notable increase in the amount of weight bench pressed and reps completed. Increase in short-term performance such as sprinting. Increase in body mass (2.4 kg).
Ferguson and Syrotuik (2006)	No improvement in strength or lean body mass.
Becque et al. (2000)	Increase in range of motion in arm flexor. Increase in fat-free muscle mass.
Volek et al. (2004)	Maintained muscular performance during the training.
Izquierdo et al. (2002)	There was no improvement in upper body strength nor in endurance.
Mujika et al. (2000)	Increase in short-term performance such as sprinting. Improvement in jumping activities after high-intensity exercise.
Tarnopolsky et al. (2001)	Increase in strength. Experience greater gains with regard to mass.
Syrotuik et al. (2001)	There was no difference in the athletes' performance.

Table 1 summarizes the effect of creatine on the performance of human beings. It displays the findings of athletes who were supplemented creatine in controlled doses over a period of time. As shown by the Table 1, creatine is capable of expediting the amount of time it takes for an individual to gain muscle mass. Creatine allows for faster gains in mass because creatine supplementation regulates the regeneration process by reduction of muscle damage-induced inflammation (Vulturar et al., 2021). The finding of (Becque et al., 2000) was that the athletes had an increase in fat-free muscle mass after being supplemented with creatine. When compared to the athletes who were given placebo pills, the athletes who supplemented creatine were able to gain muscle mass faster.

Creatine also increases the lean body mass of an individual. According to the study conducted by (Vulturar et al., 2021), A typical creatine loading period (first 5-7 days) resulted in a 0.6-2.0 kg gain in lean body mass. If creatine is supplemented for a longer duration (six to eight weeks), the amount of lean muscle mass gained increases to around 3 kilograms (Vulturar et al., 2021). Gaining lean muscle mass is a goal of many athletes and through the supplementation of creatine, athletes are able to achieve this goal faster. The study (Chrusch et al., 2001) is an example of athletes gaining lean muscle mass through creatine supplementation. The athletes who participated in the study had an increase in lean muscle mass after being supplemented 0.3g of creatine for each kilogram of body weight for the loading phase (5 days) and 0.07g of creatine for each kilogram of body weight for 11 weeks after the loading phase as shown in Table 1.

Table 1 also summaries the studies that conclude creatine has the ability to improve strength and endurance in athletes. In their study (Kreider et al., 1998) reported findings of a significant increase in the amount of weight athletes could lift during training. Two studies (Kreider et al., 1998; Mujika et al., 2000), found that athletes were able to improve their endurance. This improvement in endurance was shown by their enhanced sprinting performance and jumping abilities after performing high intensity exercises. The study (Chrusch et al., 2001) found that athletes were able to improve both their strength and endurance. Other studies in Table 1 also show that creatine has been consistently reported to increase muscle creatine content and improve high-intensity ex-ercise

capacity.

3. Creatine Supplement for Young Athletes

Creatine is a popular and well-researched supplement that is often used by athletes, including young athletes, to enhance sports performance. It is worth noting that creatine is most beneficial to younger athletes. Numerous studies have demonstrated the safety and efficacy of creatine supplementation in various populations, including adolescents. The clinical trials conducted in the article (Wu et al., 2022) show that the beneficial effects of creatine were prominent in young athletes. Since creatine improves what is already present in the body, it is not uncommon that creatine provides better results for younger athletes. This is because as one ages, their body naturally loses strength and power. For this reason, creatine supplementation is frequently effective at increasing muscular strength and lean body mass in younger athletes (Wu et al., 2022). Similarly, creatine supplements improve strength and lean muscle mass during high-intensity, short-duration exercises, such as weight lifting for athletes around 20 years of age (Mount Sinai). With that being said, it is not the case that creatine has no benefits for older athletes. The participants of the Brose et al study (Brose et al., 2003) were older individuals who gained muscle strength and saw an increase in total and fat-free mass. Similarly, the participants of the Chrusch et al study (Chrusch et al., 2001), thirty older men saw an increase in strength, endurance, and lean muscle mass as a result of creatine supplementation.

Creatine supplementation, when used responsibly and in consultation with healthcare professionals, can be a safe and effective option for young athletes looking to enhance their performance. It's important to focus on a well-rounded approach that includes proper training, nutrition, and recovery in conjunction with any supplement use. Before starting any supplement regimen, especially for young individuals, it's advisable to consult with a healthcare professional, such as a pediatrician or sports medicine doctor.

4. Potential Effect of Creatine Supplementation on Kidney

A concern regarding creatine is that it may negatively impact the kidneys. It is known that athletes tend to have a high-protein diet and since too much protein can add strain to an individual's kidneys, there is concern that the combination of creatine and a high-protein diet could be harmful for the kidneys. There is some truth to this statement because while creatine itself is not harmful, the presence of creatine in athletes who have pre-existing kidney problems is dangerous (Mount Sinai). To investigate this concern, Lugaresi et al (Lugaresi et al., 2013) conducted an experiment to determine the effects of creatine on the kidneys of athletes who have a high protein diet. The participants were supplemented with creatine and the results showed that the combination of creatine supplements and a high-protein diet was safe for healthy athletes. It was found that the results agree with other investigations that have demonstrated the safety of creatine supplementation on kidney function in distinct populations, and that Creatinine clearance, serum and urinary urea, electrolytes, proteinuria, and albuminuria remained virtually unchanged. Additionally, after studying different indexes of kidney functions, Davani et al (Davani-Davari et al., 2018) found that there are no major concerns regarding both short-term to long term use (5 days to 5 years) of creatine with supplementation ranging from 5 grams a day to 30 grams a day. As long as an individual has not had previous problems with their kidney, creatine is safe for them.

Similarly, the study of Poortmans et al (Poortmans et al., 1997) found that there was no significant change in the amount of serum and urine creatinine in healthy men who consumed creatine short term. While the study of Hultmen et al (Hultman et al., 1996) showed an increase in serum and urinary creatinine excretion in men, it should be noted that the men were not examined prior to the experiment to ensure healthiness. For long term usage, the study (Poortmans et al., 1997) found no significant effect on creatinine clearance, urea clearance, and albumin excretion rate. If there were to be an increase in serum creatinine concentrations in healthy individuals, the study of Robinson et al (Robinson et al., 2000) found that it was not related to renal dysfunction.

5. Some Negative Potential Effect of Creatine Supplementation

A few other negative potential results of creatine that may result if taken improperly or if taken by individuals with previously existing conditions are, weight gain, muscle cramps, muscle strains and pulls, upset stomach, diarrhea, dizziness, high blood pressure, liver dysfunction, and kidney damage (Mount Sinai), (Almeida et al., 2022; Brudnak, 2004; Francaux & Poortmans, 2006; Juhn & Tarnopolsky, 1998; Kreider, 2003; Schilling et al., 2001). In order for creatine to be beneficial, it is important that individuals ensure that they have no preexisting medical conditions, stay hydrated, and only take the recommended doses. When taken properly and under the right conditions, most studies have not found any side effects for long-term use. Lastly, those with high blood pressure or liver disease should not take creatine. Individuals who consume significant amounts of caffeine, take diuretics, or are on medications that affect kidney function should proceed with caution (Mount Sinai), (Barcelos et al., 2016;

Bizzarini & De Angelis, 2004; Brewster et al., 2006; Poortmans & Francaux, 2000). It is recommended that an individual consult with their health care provider before supplementing creatine into their diets.

6. Conclusion

Creatine is a natural substance consumed in the diet and synthesized in the body and widely utilized as an ergogenic aid for strength and performance gains. Creatine stands as a well-established and safe supplement, offering athletes, including young individuals, a valuable tool to enhance various aspects of physical performance. Its ability to support energy production, improve strength, and expedite recovery is supported by a wealth of scientific evidence. There is a large body of compelling evidence demonstrating improved high-intensity exercise capacity and lean body mass with creatine supplementation, conferring the most benefit in explosive physical activities that require short to moderate-duration bursts of high-intensity exertion. Debunking concerns about growth stunting, creatine emerges as a reliable ally in the pursuit of athletic excellence. When taken properly by healthy athletes, supplementing creatine provides several benefits that are incredibly beneficial. These benefits include more energy during training, increased strength, better endurance, and increased lean muscle mass. Creatine, particularly in its monohydrate form, exemplifies a versatile and effective supplement that is an inexpensive and excellent way for an individual to better themselves as an athlete. Given the safety and effectiveness of creatine supplementation, all healthy athletes may consider making it a part of their protein-rich diet.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

None.

Informed Consent

Obtained.

Provenance and Peer Review

Not commissioned; externally double-blind peer reviewed.

Data Availability Statement

The data that support the findings of this study are available on request.

References

Almeida, D., Pereira, R., Borges, E. Q., Rawson, E. S., Rocha, L. S., & Machado, M. (2022). Creatine supplementation improves physical performance, without negative effects on health markers, in young weightlifters. *Journal of Science in Sport and Exercise*, *4*(3), 255-265.

Ament, W., & Verkerke, G. J. (2009). Exercise and fatigue. *Sports medicine*, *39*, 389-422.

Antonio, J., & Ciccone, V. (2013). The effects of pre versus post workout supplementation of creatine monohydrate on body composition and strength. *Journal of the International Society of Sports Nutrition*, *10*(1), 36.

Antošová, M., & Plevkova, J. (n.d.). Therapeutic Uses of Creatine: New Possibilities. *BIOSYNTHESIS, THERAPEUTIC USES AND PHYSIOLOGICAL EFFECTS OF SUPPLEMENTATION*, 41.

Bachl, N. (2009). Supplementum 11. *Journal of Sports Science and Medicine*, *11*, 1-198.

Barcelos, R. P., Stefanello, S. T., Mauriz, J. L., Gonzalez-Gallego, J., & Soares, F. A. A. (2016). Creatine and the liver: metabolism and possible interactions. *Mini reviews in medicinal chemistry*, *16*(1), 12-18.

Béard, E., & Braissant, O. (2010). Synthesis and transport of creatine in the CNS: importance for cerebral functions. *Journal of neurochemistry*, *115*(2), 297-313.

Becque, M. D., Lochmann, J. D., & Melrose, D. R. (2000). Effects of oral creatine supplementation on muscular strength and body composition. *Medicine & Science in Sports & Exercise*, *32*(3), 654-658.

Bemben, M. G., Bemben, D. A., Loftiss, D. D., & Knehans, A. W. (2001). Creatine supplementation during resistance training in college football athletes. *Medicine & Science in Sports & Exercise*, *33*(10), 1667-1673.

Bizzarini, E., & De Angelis, L. (2004). Is the use of oral creatine supplementation safe?. *Journal of Sports*

Medicine and Physical Fitness, *44*(4), 411.

Braissant, O., Henry, H., Béard, E., & Uldry, J. (2011). Creatine deficiency syndromes and the importance of creatine synthesis in the brain. *Amino acids*, *40*, 1315-1324.

Brewster, L. M., Mairuhu, G., Bindraban, N. R., Koopmans, R. P., Clark, J. F., & Van Montfrans, G. A. (2006). Creatine kinase activity is associated with blood pressure. *Circulation*, *114*(19), 2034-2039.

Brose, A., Parise, G., & Tarnopolsky, M. A. (2003). Creatine supplementation enhances isometric strength and body composition improvements following strength exercise training in older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *58*(1), B11-B19.

Brudnak, M. A. (2004). Creatine: are the benefits worth the risk?. *Toxicology letters*, *150*(1), 123-130.

Burini, R. C., & Cyrino, E. S. (n.d.). Muscle ergogenic effects of creatine supplementation in resistance exercise training. *BIOSYNTHESIS, THERAPEUTIC USES AND PHYSIOLOGICAL EFFECTS OF SUPPLEMEN-TATION*, 71.

Butts, J., Jacobs, B., & Silvis, M. (2018). Creatine use in sports. *Sports health*, *10*(1), 31-34.

Chrusch, M. J., Chilibeck, P. D., Chad, K. E., Davison, K. S., & Burke, D. G. (2001). Creatine supplementation combined with resistance training in older men. *Medicine & Science in Sports & Exercise*, *33*(12), 2111-2117.

Cohen, P. H. (2005). Athletes may be afflicted by a wide variety of genitourinary problems. *Expert Guide to Sports Medicine*, 149.

Cooke, M. B., Rybalka, E., Williams, A. D., Cribb, P. J., & Hayes, A. (2009). Creatine supplementation enhances muscle force recovery after eccentrically-induced muscle damage in healthy individuals. *Journal of the International Society of Sports Nutrition*, *6*(1), 13.

Cooper, R., Naclerio, F., Allgrove, J., & Jimenez, A. (2012). Creatine supplementation with specific view to exercise/sports performance: an update. *Journal of the International Society of Sports Nutrition*, *9*(1), 33.

Cunha, M. P., Pazini, F. L., Oliveira, Á., & Rodrigues, A. L. S. (2013). The Role of Creatine in the Pathophysiology of Depression and the Possible Mechanisms Underlying its Antidepressant Effect. *BIOSYNTHESIS, THERAPEUTIC USES AND PHYSIOLOGICAL EFFECTS OF SUPPLEMENTATION*, 1.

Curt, M. J. C., Voicu, P. M., Fontaine, M., Dessein, A. F., Porchet, N., Mention-Mulliez, K., ... & Vamecq, J. (2015). Creatine biosynthesis and transport in health and disease. *Biochimie*, *119*, 146-165.

Davani-Davari, D., Karimzadeh, I., Ezzatzadegan-Jahromi, S., & Sagheb, M. M. (2018). Potential adverse effects of creatine supplement on the kidney in athletes and bodybuilders. *Iranian journal of kidney diseases*, *12*(5), 253.

D'Cruz, F., & Ribeiro, V. (Eds.). (2013). *Creatine: Biosynthesis, Therapeutic Uses and Physiological Effects of Supplementation*. Nova Biomedical.

de Salles Painelli, V., Alves, V. T., Ugrinowitsch, C., Benatti, F. B., Artioli, G. G., Lancha, A. H., ... & Roschel, H. (2014). Creatine supplementation prevents acute strength loss induced by concurrent exercise. *European journal of applied physiology*, *114*(8), 1749-1755.

Ergen, E., Ülkar, B., & Güner, R. (n.d.). *JOURNAL OF SPORTS SCIENCE & MEDICINE*.

Ferguson, T. B., & Syrotuik, D. G. (2006). Effects of creatine monohydrate supplementation on body composition and strength indices in experienced resistance trained women. *The Journal of Strength & Conditioning Research*, *20*(4), 939-946.

Francaux, M., & Poortmans, J. R. (2006). Side effects of creatine supplementation in athletes. *International journal of sports physiology and performance*, *1*(4), 311-323.

Greenhaff, P. L. (1997). The nutritional biochemistry of creatine. *The Journal of Nutritional Biochemistry*, *8*(11), 610-618.

Guzun, R., Timohhina, N., Tepp, K., Gonzalez-Granillo, M., Shevchuk, I., Chekulayev, V., ... & Saks, V. A. (2011). Systems bioenergetics of creatine kinase networks: physiological roles of creatine and phosphocreatine in regulation of cardiac cell function. *Amino acids*, *40*, 1333-1348.

Hall, M., Manetta, E., & Tupper, K. (2021). Creatine supplementation: an update. *Current sports medicine reports*, *20*(7), 338-344.

Hall, M., & Trojian, T. H. (2013). Creatine supplementation. *Current sports medicine reports*, *12*(4), 240-244.

Howatson, G., & Van Someren, K. A. (2008). The prevention and treatment of exercise-induced muscle damage. *Sports medicine*, *38*, 483-503.

Hultman, E., Soderlund, K., Timmons, J. A., Cederblad, G., & Greenhaff, P. L. (1996). Muscle creatine loading in men. *Journal of applied physiology*, *81*(1), 232-237.

Hunter, A. M., Galloway, S. D., Smith, I. J., Tallent, J., Ditroilo, M., Fairweather, M. M., & Howatson, G. (2012). Assessment of eccentric exercise-induced muscle damage of the elbow flexors by tensiomyography. *Journal of Electromyography and Kinesiology*, *22*(3), 334-341.

Izquierdo, M. I. K. E. L., Ibanez, J. A. V. I. E. R., González-Badillo, J. J., & Gorostiaga, E. M. (2002). Effects of creatine supplementation on muscle power, endurance, and sprint performance. *Medicine & Science in Sports & Exercise*, *34*(2), 332-343.

Jäger, R., Purpura, M., Shao, A., Inoue, T., & Kreider, R. B. (2011). Analysis of the efficacy, safety, and regulatory status of novel forms of creatine. *Amino acids*, *40*, 1369-1383.

Jiaming, Y., & Rahimi, M. H. (2021). Creatine supplementation effect on recovery following exercise-induced muscle damage: A systematic review and meta-analysis of randomized controlled trials. *Journal of food biochemistry*, *45*(10), e13916.

Juhn, M. S., & Tarnopolsky, M. (1998). Potential side effects of oral creatine supplementation: a critical review. *Clinical journal of sport medicine*, *8*(4), 298-304.

Kerksick, C. M., Wilborn, C. D., Campbell, W. I., Harvey, T. M., Marcello, B. M., Roberts, M. D., ... & Greenwood, M. (2009). The effects of creatine monohydrate supplementation with and without D-pinitol on resistance training adaptations. *The Journal of Strength & Conditioning Research*, *23*(9), 2673-2682.

Kraemer, W. J., & Volek, J. S. (1999). Creatine supplementation: its role in human performance. *Clinics in sports medicine*, *18*(3), 651-666.

Kreider, R. B. (2003). Effects of creatine supplementation on performance and training adaptations. *Molecular and cellular biochemistry*, *244*, 89-94.

Kreider, R. B., Ferreira, M., Wilson, M., Grindstaff, P., Plisk, S., Reinardy, J., ... & Almada, A. L. (1998). Effects of creatine supplementation on body composition, strength, and sprint performance. *Medicine and science in sports and exercise*, *30*, 73-82.

Li, X. H., Chen, X. J., Ou, W. B., Zhang, Q., Lv, Z. R., Zhan, Y., ... & Zhou, H. M. (2013). Knockdown of creatine kinase B inhibits ovarian cancer progression by decreasing glycolysis. *The International Journal of Biochemistry & Cell Biology*, *45*(5), 979-986.

Lugaresi, R., Leme, M., de Salles Painelli, V., Murai, I. H., Roschel, H., Sapienza, M. T., ... & Gualano, B. (2013). Does long-term creatine supplementation impair kidney function in resistance-trained individuals consuming a high-protein diet?. *Journal of the International Society of Sports Nutrition*, *10*(1), 26.

Mujika, I., Padilla, S. A. B. I. N. O., Ibanez, J. A. V. I. E. R., Izquierdo, M. I. K. E. L., & Gorostiaga, E. S. T. E. B. A. N. (2000). Creatine supplementation and sprint performance in soccer players. *Medicine & Science in Sports & Exercise*, *32*(2), 518.

Owens, D. J., Twist, C., Cobley, J. N., Howatson, G., & Close, G. L. (2019). Exercise-induced muscle damage: What is it, what causes it and what are the nutritional solutions?. *European journal of sport science*, *19*(1), 71-85.

PANEL, E. (2009). Selected issues for the adolescent athlete and the team physician: a consensus statement. *SPORTS MEDICINE*.

Pittas, G., Hazell, M. D., Simpson, E. J., & Greenhaff, P. L. (2010). Optimization of insulin-mediated creatine retention during creatine feeding in humans. *Journal of sports sciences*, *28*(1), 67-74.

Poortmans, J. R., Auquier, H., Renaut, V., Durussel, A., Saugy, M., & Brisson, G. R. (1997). Effect of short-term creatine supplementation on renal responses in men. *European journal of applied physiology and occupational physiology*, *76*, 566-567.

Poortmans, J. R., & Francaux, M. (2000). Adverse effects of creatine supplementation: fact or fiction?. *Sports Medicine*, *30*, 155-170.

Rahal, A., Kumar, A., Singh, V., Yadav, B., Tiwari, R., Chakraborty, S., & Dhama, K. (2014). Oxidative stress, prooxidants, and antioxidants: the interplay. *BioMed research international*, *2014*.

Robinson, T. M., Sewell, D. A., Casey, A., Steenge, G., & Greenhaff, P. L. (2000). Dietary creatine supplementation does not affect some haematological indices, or indices of muscle damage and hepatic and renal function. *British journal of sports medicine*, *34*(4), 284-288.

Sandler, D. (2005). *Sports power*. Human kinetics.

Schilling, B. K., Stone, M. H., Utter, A. L. A. N., Kearney, J. T., Johnson, M., Coglianese, R., ... & Stone, M. E. (2001). Creatine supplementation and health variables: a retrospective study. *Medicine & Science in Sports & Exercise*, *33*(2), 183-188.

Shadowen, M. (n.d.). Supplement Spotlight: Break Through with Creatine.

Syrotuik, D. G., Game, A. B., Gillies, E. M., & Bell, G. J. (2001). Effects of creatine monohydrate supplementation during combined strength and high intensity rowing training on performance. *Canadian Journal of Applied Physiology*, *26*(6), 527-542.

Tarnopolsky, M. A., Parise, G., Yardley, N. J., Ballantyne, C. S., Olatunji, S., & Phillips, S. M. (2001). Creatine-dextrose and protein-dextrose induce similar strength gains during training. *Medicine & Science in Sports & Exercise*, *33*(12), 2044-2052.

Tietze, D. C., & Borchers, J. (2014). Exertional rhabdomyolysis in the athlete: a clinical review. *Sports Health*, *6*(4), 336-339.

Volek, J. S., Ratamess, N. A., Rubin, M. R., Gomez, A. L., French, D. N., McGuigan, M. M., ... & Kraemer, W. J. (2004). The effects of creatine supplementation on muscular performance and body composition responses to short-term resistance training overreaching. *European journal of applied physiology*, *91*, 628-637.

Vulturar, R., Jurjiu, B., Damian, M., Bojan, A., Pintilie, S. R., Jurcă, C., ... & Grad, S. (2021). Creatine supplementation and muscles: From metabolism to medical practice. *Romanian JouRnal of medical PRactice*, *16*(3), 80.

Walker, D. W., Dickinson, H., Ellery, S. J., LaRosa, D. A., Ireland, Z. J., Baharom, S., ... & Snow, R. (2013). Experimental evidence that Creatine supplementation during pregnancy is protective ror the neonate. In *Creatine Biosynthesis, Therapeutic Uses and Physiological Effects of Supplementation* (pp. 101-127). Nova Science Publishers.

Wallimann, T., Tokarska-Schlattner, M., & Schlattner, U. (2011). The creatine kinase system and pleiotropic effects of creatine. *Amino acids*, *40*, 1271-1296.

Wang, C. C., Fang, C. C., Lee, Y. H., Yang, M. T., & Chan, K. H. (2018). Effects of 4-week creatine supplementation combined with complex training on muscle damage and sport performance. *Nutrients*, *10*(11), 1640.

Williams, M. H., Kreider, R. B., & Branch, J. D. (1999). *Creatine: The power supplement*. Human kinetics.

Wu, S. H., Chen, K. L., Hsu, C., Chen, H. C., Chen, J. Y., Yu, S. Y., & Shiu, Y. J. (2022). Creatine supplementation for muscle growth: a scoping review of randomized clinical trials from 2012 to 2021. *Nutrients*, *14*(6), 1255.

Wyss, M., & Kaddurah-Daouk, R. (2000). Creatine and creatinine metabolism. *Physiological reviews 80*(3), 1107-1213.