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Athletes Who Consume Creatine Have a Greater Muscle Mass and Sports Performance: A Systematic Review

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Abstract

Creatine monohydrate supplementation is used in numerous sports to enhance an athlete's performance by improving lean muscle mass. Athletes and men and women, who participate in recreational sports, take creatine before, during, or after training whether they are in the weight room or on the field/court. Creatine can also improve muscle recovery from intense exercise. This systematic review aims to assess the effects of creatine supplementation on an athlete's muscle mass growth. A literature search was conducted utilizing two databases which included PubMed and Sports Discus. The databases discovered randomized controlled trials published between 2014 to 2024, using combinations of the search terms: "athletes," "sports," "athletics," AND "creatine," AND "muscle mass," "hypertrophy," AND "sports performance." Reference lists of appropriate studies were manually searched for additional articles. The thirty-three studies offer support for the usage of creatine to improve lean muscle mass and sports performance. The results of this systematic review indicated muscle mass in athletes can increase significantly by creatine supplementation.

Keywords: creatine, athletes, muscle mass, muscle hypertrophy, lean mass, training, performance

1. Introduction

Creatine is an organic compound important for energy storage as it is phosphorylated to creatine phosphate, which serves as a phosphate donor in the conversion of adenosine diphosphate (ADP) to adenosine triphosphate (ATP) and supplies the energy necessary for muscle contraction (National Center for Biotechnology Information, 2022). According to the Cleveland Clinic (2023), creatine has helped amateur and professional athletes create a “quick burst” of energy and increase muscle strength. In addition to its popularity in the consumer realm, creatine’s ability to intensify or increase some types of exercise performance has arguably been among the most researched topics in sports nutrition literature for the past 25 years (Wax et al., 2021). Creatine supplementation can positively increase muscle hypertrophy in the upper limbs of resistance-trained young men (Nunes et al., 2017). This review focuses on athletes who use creatine supplements to enhance muscle hypertrophy and improve sports performance, emphasizing research from the past 10 years.

2. Methods

This systematic review followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines (Page et al., 2021)

2.1 Protocol and Registration

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement, this systematic review was registered with PROSPERO—International Prospective Register of Systematic Reviews (CRD42022321350).

2.2 Search Strategy

A literature search was conducted utilizing two databases which included PubMed and Sports Discus. The databases discovered randomized controlled trials (RCTs) published between 2014 and 2024. The search terms (Table 1) included: “athletes,” “sports,” “athletics,” and “creatine,” and “muscle mass,” “hypertrophy,” and “sports performance.” Reference lists of appropriate studies were manually searched for additional articles.

Table 1. The Population, Intervention, Comparison, Outcome (PICO) model

Patient/Problem	Intervention	No Comparison/Control Group Used	Outcomes
Athletes	Creatine		Muscle mass
Sports			Sports performance
Athletics			Hypertrophy

2.3 Eligibility Criteria

The eligibility criteria included: (1) participants between the ages of 14-50 years old; (2) both males and females from the United States and other countries; (3) physically active or sports athletes in good health; (4) consistently participated in resistance training; (5) participants who did not consume alcohol within 48 hours before sampling days; (6) studies with more than 14 participants.

Studies were excluded if: (1) participants were under the age of 13 and older than 51 years old; (2) participants were pregnant and/or breastfeeding; (3) participants suffered from chronic diseases such as diabetes, kidney disease, heart disease, Parkinson’s disease, kidney disease, and liver disease; (4) study included less than 13 participants; and (5) published in non-peer-reviewed journal and articles not in English. See Table 2 for full details on the inclusion and exclusion criteria of this systemized review.

Table 2. Inclusion and exclusion criteria

	Inclusion Criteria	Exclusion Criteria
Study Design	Randomized Controlled Trials (RCTs), meta-analysis in peer-reviewed journals	Reviews and case studies; articles in non-peer-reviewed journals
Size of Study Group	> 14 participants in each group	<14 participants in each group
Language	Limited to articles available in English	Articles not available in English
Age	Ages between 14-50 years old	Participants under the age of 13 and older than 51 years old
Gender and country	Males and females from the United States and other countries around the world	N/A
Health Status/Condition	Physically active males and females who are in good health such as sports athletes and individuals undergoing resistance training.	Participants who (1) were pregnant and/or breastfeeding, (2) suffer from chronic medical conditions such as diabetes, kidney disease, heart disease, hypertension, Parkinson’s, and liver disease, (3) did not consume alcohol within 48 hours before sampling days, and (4) were not physically active
Exposure	Athletes who consume creatine	Athletes who consume other supplements than creatine
Outcome	Studies reported an increase in muscle mass in the participants.	Studies that do not report an increase in muscle mass in the participants.
Publication date	Published between 2014 and 2024	Published before 2013 or after 2025

2.4 Data Extraction and Quality Assessment

Data from the included articles were extracted by the primary author using an adapted data collection form (Cochrane Training, 2021). All articles within the search results that did not report using creatine, presented the wrong population and study size, and did not meet the eligibility criteria were excluded. All steps highlighting the screening of the relative information are presented in Figure 1. Data were extracted and adapted from the Cochrane database including author, study design, publication date, sample size, study characteristics, language, and health status (Cochrane Training, 2021, Ryan et al, 2016). The Academy of Nutrition and Dietetics Quality Criteria Checklist (QCC) for Primary Research, includes four relevance questions and ten validity questions, searching for the risk of bias, study design, sample size, and blinding of results (Academy of Nutrition and Dietetics, 2016). The studies were assigned with three symbols: positive (+), negative (-), and neutral (ɵ). With a positive rating, studies indicated the report has addressed the issues of the inclusion and exclusion criteria, bias, data collection, and analysis of the study. A study that received a negative symbol, indicated not all the issues were addressed. Lastly, a neutral symbol issued indicated the evidence was neither strong nor addressed.

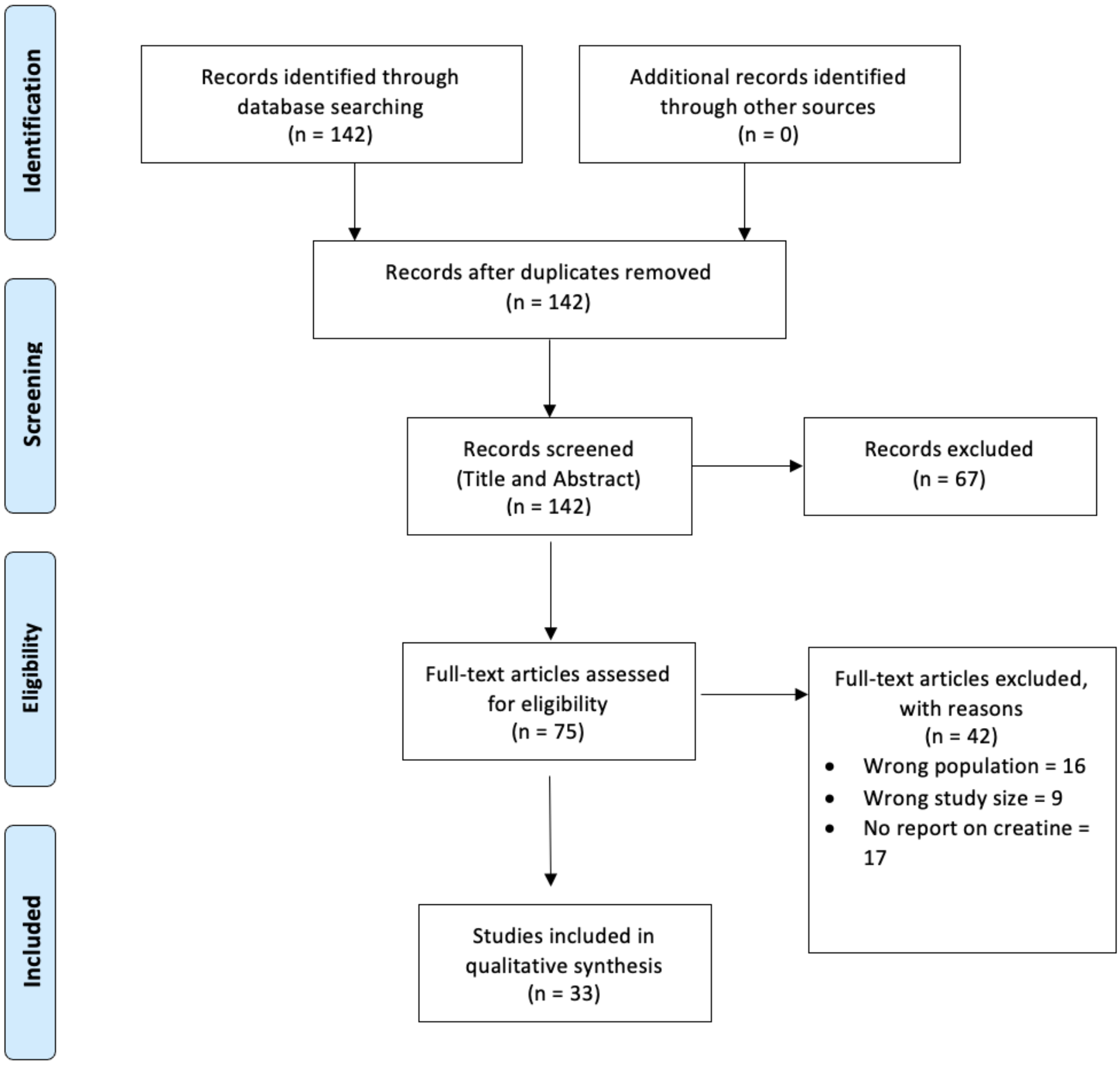

Figure 1. PRISMA flow diagram of search strategy, study selection, and identification process of eligible studies for a systematic review of an increase in muscle mass on outcomes for athletes that consume creatine

3. Results

The literature search identified a total of 142 articles related to the established inclusion/exclusion criteria; however, only 33 of the 142 articles met all inclusion criteria. From the 142 articles screened by the primary author, 67 articles were removed because they did not match the pre-established criteria. From the remaining 75 full-text articles assessed for eligibility, another 42 articles were excluded because the articles were unrelated to creatine-promoting muscle hypertrophy and sports performance. The topics and number of studies excluded were: 16 articles showed a population outside of the age requirements; nine articles noted an undesired study size; and 17 articles with no report on creatine. Thus, 33 studies were included in this study.

3.1 Team Sports

Creatine was measured by reviewing the effect of ingesting the supplement in athletes playing sports including basketball, football, rowing, soccer, swimming, and taekwondo (see Table 3). A randomized, open-labeled study by Vargas-Molina et al (2022), reviewed 23 male U16 basketball players for strength training and muscle mass in a resistance and plyometric training program. Vargas-Molina et al (2022) concluded creatine monohydrate supplementation significantly increased ($p < 0.01$) strength-training adaptations, muscle mass, and sports performance in U16 basketball players undergoing a resistance and plyometric training program.

Three studies reported creatine consumption in football. Kreider et al (2017), conducted a randomized control trial on 25 NCAA Division 1A football players in resistance/agility training. Twenty-eight days of taking creatine supplementation during resistance/agility training significantly increased ($p < 0.05$) greater gains in fat/muscle mass, isotonic lifting volume, and sprint performance. In addition, Maughan et al (2018) evaluated 25 football players taking 20g/day for a week during the creatine loading phase and showed a significant increase ($p < 0.05$) in the creatine-supplemented group with a 1-2 kg muscle mass increase. Wax et al (2021) also reported 42 American football players taking creatine had significantly enhanced ($p < 0.05$) training adaptations on various types of training associated with body, muscle mass/composition, maximum strength, and static vertical jump. Overall, creatine supplementation showed improvements in muscle mass and training performances in the sport of football.

Six studies reviewed the impact of creatine in soccer. In a randomized controlled trial by Fernandes (2021), 19 elite soccer players in the creatine group significantly improved ($p < 0.05$) muscle hypertrophy and their soccer performance on the field. Moreover, 118 males and 50 female soccer players took creatine in Mieglo-Ayuso et al's (2019) study and showed beneficial effects on muscle hypertrophy and anaerobic performance tests (SMD, 1.23; 95% CI, 0.55-1.91; $p < 0.001$). A randomized control trial was conducted by Ramirez-Campillo et al (2016) highlighting the creatine plyometric training group improved significantly ($p < 0.05$) in their jumps, muscle mass, and repeated sprinting performance compared to the control and placebo groups. However, 16 male amateur soccer players in the Williams et al (2014) study, showed no differences ($p > 0.05$) in lean muscle mass between the creatine and placebo groups. Additionally, 19 male soccer players in Yanez-Silva et al (2017) study, indicated a short-term, low-dose, of oral creatine monohydrate supplementation significantly ($p < 0.05$) affected muscle power and mass in soccer players. A significant difference in the creatine group ($p < 0.05$) was displayed by 21 healthy male soccer reported by Yapici (2023). In conclusion, soccer players who consumed creatine displayed significant improvements in muscle hypertrophy, plyometric training, and sports performance.

Regarding other sports, there was a significant increase in 41 trained taekwondo athletes for lean muscle mass ($p < 0.001$) noted by Sarshin et al (2021). Additionally, Jagim and Kerksick (2021) reported 18 male and female junior competitive swimmers' intakes over nine days of creatine supplementation during swim training provided a significant increase ($p < 0.05$) in muscle mass and ergogenic value to competitive swimmers. Fernandez-Landa et al (2020) observed 28 elite male traditional rowers absorb an oral supplementation of creatine monohydrate over 10 weeks resulting in a significant increase ($p < 0.05$) effect on muscle hypertrophy and aerobic power during an incremental test. Swimmers, rowers, and taekwondo athletes present positive results in muscle mass and their performance levels when creatine is consumed.

Table 3. Team Sports Summary

Author, Year	Number of Patients/Studies	Results	Quality of Bias Rating
Vargas-Molina, S et al., 2022	23 male U16 basketball players	Creatine monohydrate supplementation significantly increased ($p < 0.01$) strength-training adaptations, muscle mass, and sports performance in U16 basketball players undergoing a resistance and plyometric training program.	Risk: Positive. Validity: Neutral. Lack of inclusion criteria, small sample size.
Kreider, RB et al., 2017	25 NCAA Division IA football players	28 d of creatine supplementations (15.75 g•d^{-1}) during resistance/agility training significantly increased ($p < 0.05$) greater gains in fat/muscle mass, isotonic lifting volume, and sprint performance.	Risk: Positive. Validity: Positive. Reporter bias.
Maughan, R et al., 2018	25 players under age 20 years	There were significant increases ($p < 0.05$) in the creatine-supplemented group with 1-2kg MM increase after creatine loading.	Risk: Positive. Validity: Neutral. Inclusion and exclusion not specified.
Wax, B et al., 2021	42 American football players.	The creatine supplement significantly enhanced ($p < 0.05$) training adaptations associated	Risk: Positive. Validity: Positive. Reporter bias.

		with body, muscle mass/composition, maximum strength, and static vertical jump.	
Fernandes, H, 2021	19 soccer players supplemented with creatine	The elite soccer players in the creatine group significantly improved ($p < 0.05$) muscle hypertrophy and performance on the field.	Risk: Positive. Validity: Neutral. Small sample size, inclusion and exclusion not specified, reporter bias.
Mieglo-Ayuso, J, et al., 2019	168 soccer players (118 males, 50 females)	Creatine supplementation showed beneficial effects on muscle hypertrophy and on anaerobic performance tests (SMD, 1.23; 95% CI, 0.55-1.91; $p < 0.001$).	Risk: Positive. Validity: Neutral. Lack of studies.
Ramirez-Campillo, R et al., 2016	30 young female soccer players	The creatine plyometric training group significantly ($p < 0.05$) improved more in the jumps, muscle mass and repeated sprinting performance than the control and the placebo groups.	Risk: Positive. Validity: Positive. Reporter bias.
Williams, J et al., 2014	16 male amateur soccer players	No differences ($p > 0.05$) in lean muscle mass after creatine supplementation.	Risk: Positive. Validity: Neutral. Lack of evidence, small sample size.
Yanez-Silva, A et al., 2017	19 male soccer players	Results indicate a low-dose, short-term oral creatine monohydrate supplementation significantly ($p < 0.05$) affected muscle power and mass in soccer players.	Risk: Positive. Validity: Neutral. Inclusion and exclusion criteria not specified, small sample size.
Yapici A, 2023	21 healthy male soccer players	There is a significant difference in the creatine group ($p < 0.05$).	Risk: Positive. Validity: Neutral. Small sample size.
Sarshin, A et al., 2021	41 trained taekwondo athletes	There was a significant increase in the creatine group for lean muscle mass ($p < 0.001$).	Risk: Positive. Validity: Positive. Outcomes of measurement bias.
Jagim, AR &	18 male and	Nine days of creatine	Risk: Positive.

Kerksick CM, 2021	female junior competitive swimmers	supplementation during swim training provide a significant increase ($p < 0.05$) in muscle mass and ergogenic value to competitive swimmers.	Validity: Neutral. Small sample size.
Fernandez-Landa, J et al., 2020	28 elite male traditional rowers	An oral supplementation of creatine monohydrate over 10 weeks of training showed a significant increases ($p < 0.05$) effect on muscle hypertrophy and aerobic power during an incremental test.	Risk: Positive. Validity: Positive. Outcome of measurement bias.

3.2 Resistance Training

Ten studies present the effects of taking creatine during resistance training (see Table 4). Forty-four outcomes were analyzed and examined by Burke et al (2023) on the combined effects of resistance training and creatine supplementation. Results from this research suggest creatine combined with resistance training promoted a small, significant increase ($p < 0.01$) in muscle hypertrophy in both the upper and lower body. In Butts et al (2017) study, there were significant ($p < 0.05$) improvements with doses ranging from 0.07 g per kg body weight per day to 5 g/day. This reveals favorable outcomes for creatine with resistance training for increasing lean muscle mass. Additionally, Fernandez-Landa et al (2023) reported a significant ($p < 0.05$) change in endurance performance and muscle hypertrophy after creatine monohydrate supplementation was consumed during resistance training. Creatine was examined on muscle hypertrophy by Forbes et al (2023), and the authors found a significant increase ($p = 0.03$) in muscle mass and endurance performance during resistance training. Moreover, Forbes et al (2021) highlighted 16 RCTs with 18 treatment arms ($n = 509$) significantly increased ($p < 0.05$) lean muscle mass with creatine supplementation and resistance training. Kaufman et al (2022) reported significant improvements ($p < 0.001$) in muscle mass, via skeletal muscle hypertrophy with increased lean tissue production in creatine. Five hundred sixty-three individuals, who are vegetarians, had taken creatine in resistance training and displayed a significant increase ($p < 0.05$) in lean muscle mass, type 2 fiber area, muscular strength, and muscle endurance Kaviani et al (2020). Furthermore, Peeling et al (2019) reported a significant increase ($p < 0.05$) in muscle mass, power, strength, short-repeated bouts of high-intensity exercise, and resistance training while consuming creatine supplementation. Sims et al (2023) noted taking 3-5g of creatine per day with resistance training is significant for female athletes and leads to an increase ($p < 0.05$) in muscle strength, hypertrophy, and performance. Lastly, Sousa-Silva et al (2023) evaluated 17 healthy males who showed a significant increase ($p < 0.05$) in muscle performance at 30% during traditional resistance training. All ten studies indicated resistance training made a significant impact on individuals who use creatine.

Table 4. Resistance Training Summary

Author, Year	Number of Patients/Studies	Results	Quality of Bias Rating
Burke, R et al., 2023	44 outcomes were analyzed and examined the combined effects of resistance training (RT) and creatine supplementation. A pooled mean estimate of 0.11	Results suggest that creatine supplementation combined with resistance training promotes a small significant increase (p < 0.01) in the direct measures of muscle hypertrophy in both the upper and lower body.	Risk: Positive. Validity: Positive. Lack of research evidence, reporter bias.
Butts, J et al., 2017	A meta-analysis including 100 studies demonstrated significant improvements in laboratory-based exercise after short-term creatine supplementation.	Creatine doses ranging from 0.07 g per kg body weight per day to 5 g/d revealed favorable outcomes for creatine with resistance training for a significant (p < 0.05) increase in lean muscle mass.	Risk: Positive. Validity: Positive. Lack of research, reporter bias.
Fernandez-Landa, J et al., 2023	Total of 13 studies satisfied all the eligibility criteria and were included in this systematic review and meta-analysis.	A significant (p < 0.05) change in endurance performance and muscle hypertrophy after creatine monohydrate supplementation in a trained population.	Risk: Positive. Validity: Neutral. Small sample sizes.
Forbes, SC et al., 2023	13 systematic reviews and meta-analysis studies examined creatine supplementation on muscle hypertrophy, during resistance training.	Creatine causes a significant increase (p = 0.03) in muscle mass, which may be detrimental to endurance performance, in resistance training.	Risk: Positive. Validity: Neutral. Lack of evidence and research, reporter bias.
Forbes, SC et al., 2021	Individual studies (n = 20) are mixed, with 10 studies showing beneficial effects on measures of lean muscle mass and/or strength.	16 RCTs with 18 treatment arms (n = 509) revealed that creatine supplementation and resistance training significantly increased (p < 0.05) measures of lean muscle mass.	Risk: Positive. Validity: Neutral. Inclusion and exclusion not specified.
Kaufman, M et	Eight studies systematic	Creatine significantly	Risk:

al., 2022	review and meta-analysis have shown that creatine supplements improve muscle hypertrophy and performance in athletes.	improved ($p < 0.001$) muscle mass via skeletal muscle hypertrophy with increased lean tissue production.	Positive. Validity: Neutral. Lack of studies, lack of evidence, small sample size.
Kaviani, M et al., 2020	53 studies (563 individuals in the creatine supplementation group as vegetarians)	Creatine supplementation during resistance training in vegetarians significantly increase ($p < 0.05$) lean tissue mass, type 2 fiber area, muscular strength, and muscle endurance.	Risk: Positive. Validity: Neutral. Lacking inclusion criteria, reporter bias.
Peeling, P et al., 2019	159 studies systematic review and meta-analysis studies in athlete populations investigating the prevalence of the supplement creatine used for muscle mass and strength.	Creatine supplementation consumed for both acute and chronic performance shows a significant increase ($p < 0.05$) in muscle mass, power, strength, and short-repeated bouts of high-intensity exercise.	Risk: Positive. Validity: Neutral. Lack of evidence.
Sims, ST et al., 2023	18 studies published on creatine supplementation for women is growing with resistance training benefiting muscle strength, hypertrophy, and performance.	Creatine is highly efficacious for female athletes. Creatine supplementation of 3 to 5g per day is recommended for the mechanistic support of creatine supplementation and leads an increase ($p < 0.05$) in muscle strength, growth factors.	Risk: Positive. Validity: Positive. Reporter bias.
Sousa-Silva R et al., 2023	17 healthy males	Creatine supplementation exerted a hypertrophic effect when utilized with TRAD and significant increase ($p < 0.05$) muscle performance at 30% 1RM.	Risk: Positive. Validity: Neutral. Lack of inclusion, small sample size, reporter bias.

3.3 Recreational Athletes

Eight studies were reviewed on recreational athletes and the consumption of creatine (see Table 5). Askow et al (2022) observed a significant ($p = 0.011$) increase in lean muscle mass over the Cr supplementation period. Sixteen recreational males in the creatine group had a significant ($p = 0.007$) increase in body and muscle mass after supplementation (0.99 ± 0.83 kg) (Bogdanis et al, 2022). Hall et al (2021) reported that 18–35-year-old active adolescents showed a safe and effective way in an increase significantly ($p < 0.05$) in lean muscle mass, strength, and sports performance. A randomized controlled trial study by Nunes et al (2017), presented a significant increase ($p < 0.001$) and positively augmented muscle hypertrophy in resistance-trained young adult men. Ribeiro et al (2020) reviewed 27 resistance-trained men and presented a significant ($p < 0.05$) increase in skeletal muscle mass. CR + LOAD (loaded creatine) showed a significant ($p < 0.05$) increase in endurance-trained male cyclists and triathletes noted by Tomcik et al (2018). Wang et al (2018) reported results of 30 male university athletes in the creatine group were significantly ($p < 0.05$) greater in hypertrophy and 1-RM strength than the placebo group. In addition, Forbes et al (2017) showed no significant change ($p > 0.01$) over time in recreational female's whole-body lean muscle mass (creatine = +0.5%). In general, recreational athletes showed a positive encounter with creatine.

Table 5. Recreational Athletes

Author, Year	Number of Patients/Studies	Results	Quality of Bias Rating
Askow, AT et al., 2022	29 healthy men (n = 17) and women (n = 12) consumed 5 g/day of Cr (creatine) monohydrate (n = 8)	Lean muscle mass significantly *p* = .011) increased over the Cr supplementation period.	Risk: Positive. Validity: Neutral. Lack of inclusion and exclusion criteria, reporter bias.
Bogdanis, G et al., 2022	16 recreationally active males volunteered	The creatine group had a significant (p = 0.007) increase in body and muscle mass after supplementation by 0.99 ± 0.83 kg).	Risk: Positive. Validity: Neutral. Small sample size.
Forbes, SC et al., 2017	17 recreationally active females	No significant change ($p > 0.01$) over time in whole-body lean muscle mass (creatine = +0.5%).	Risk: Positive. Validity: Neutral. Small sample size, lack of evidence.
Hall, M et al., 2021	18-35 years old, data regarding adolescent	Short-and long-term creatine	Risk: Positive. Validity: Neutral.

	population have been scarce.	supplementation is safe and effective in an increase significantly ($p < 0.05$) lean muscle mass, strength and sports performance in healthy individuals and number of patient populations.	Lack of evidence, vague research question, reporter bias.
Nunes, J et. al, 2017	43 resistance-trained men over an 8-week study period.	The creatine supplementation group achieved greater ($p < 0.001$) increases and can positively augment muscle hypertrophy in resistance-trained young adult men.	Risk: Positive. Validity: Positive. Reporter bias.
Ribeiro, AS et al., 2020	27 resistance trained men	The creatine supplementation group showed a significant increase ($p < 0.05$) in skeletal muscle mass.	Risk: Positive. Validity: Positive. Reporter bias.
Tomcik, K et al., 2018	18 endurance-trained male cyclists and triathletes	CR + LOAD showed a significant increase ($p < 0.05$).	Risk: Positive. Validity: Neutral. Small sample size.
Wang, CC et al., 2018	30 male university athletes from baseball, basketball, and tchoukball teams volunteered	The 1-RM strength and hypertrophy in the creatine group was significantly greater than in the placebo group ($p < 0.05$).	Risk: Positive. Validity: Neutral. Inclusion criteria not specified.

3.4 Body Builders

Two studies assessed creatine taken in active bodybuilders (see Table 6). Jovanov et al (2019) highlighted a 40% strength improvement attributed to muscle hypertrophy. Stecker et al (2019) observed the PRE-POST creatine monohydrate group presented a greater ($p < 0.05$) increase in lean muscle mass and 1RM strength over the placebo group. Overall, creatine made a positive impact on bodybuilders.

Table 6. Body Builders Summary

Author, Year	Number of Patients/Studies	Results	Quality of Bias Rating
Jovanov, P et al., 2019	31 recreational male bodybuilders	Creatine provided greater improvements in 1RM strength. 40% of the strength improvements are attributed to hypertrophy of muscle involved in the exercise.	Risk: Positive. Validity: Neutral. Inclusion and exclusion not specified, vague research question.
Stecker, RA et al., 2019	23 male bodybuilders	PRE-POST CrM (creatine monohydrate) group demonstrated a greater ($p < 0.05$) increase in lean muscle mass and 1RM strength in two of three assessments.	Risk: Positive. Validity: Neutral. Inclusion and exclusion not specified.

3.5 Quality Assessment/Risk of Bias

The quality assessment of the literature was conducted using the Quality Criteria Checklist (QCC) for Primary Research, published by the Academy of Nutrition and Dietetics Evidence Analysis Library (Academy of Nutrition and Dietetics, 2016). Overall, the majority of the studies presented a “+” rating, indicating a strong quality of primary research. However, 22 studies presented neutral outcomes such as a lack of inclusion and/or exclusion criteria, vague research question, lack of evidence, sample size, reporter bias, and outcomes of measurement bias. There were no negative studies presented. In conclusion, the quality of studies resulted in a strong analysis of the quality assessment of this review.

4. Discussion

The results of the systematic review were positive for athletes and men and women who participate in sports for recreation. Using creatine monohydrate, during recreational activities or training, showed a significant ($p < 0.05$) increase in muscle hypertrophy in many of the studies ($n = 31$ or 93.9%), while two studies found no significant change in lean muscle mass ($n = 2$). The supplement is safe and efficient for athletes and men and women, who participate in recreational sports, to consume before, during, or after their workouts. In addition, using creatine in team sports and their training provides beneficial results in improving muscle mass and strength, exercise performance, and recovery time.

The studies in our systematic review presented beneficial results on creatine consumption increasing muscle hypertrophy in athletes. The effect of creatine improved in numerous environments in sports and recreational activities. Whether you are on the field or in the weight room, creatine has helped training regiments in athletes.

The impact of creatine on athletes in team sports - basketball, football, rowing, soccer, swimming, and taekwondo – was effective through their training. Creatine improved results in different training programs in each sport. Football players, who consumed creatine during resistance/agility training, increased fat/muscle mass, and sprint performance. Swimmers ingested creatine for nine days during their training. This resulted in a significant increase ($p < 0.05$) in muscle mass and ergogenic value to competitive swimmers.

Studies have also shown resistance training programs coupled with creatine supplementation benefit individuals. From lifting weights such as barbells and dumbbells to performing air squats or pushups, the use of creatine demonstrated an increase in lean muscle mass. Peeling et al (2019) showed a significant increase ($p < 0.05$) in different performances in the body, including muscle mass, power, and strength, in short, repeated bouts of high-intensity exercises and resistance training. Using creatine at doses of 0.07 g/kg of athletes' body weight, totaling 5g/day, Butts et al (2017) noted a significant ($p < 0.05$) increase in lean muscle mass. The data supports creatine demonstrating an impact on resistance training, which elevates lean muscle mass in athletes' bodies.

Furthermore, numerous studies have examined the utilization of creatine among recreational athletes. The results presented improvements in athletes' muscle hypertrophy. Wang et al (2018) reported 30 male university recreational athletes in the creatine group were significantly ($p < 0.05$) greater in hypertrophy and 1-RM strength. Additionally, Nunes et al (2017) presented a significant increase ($p < 0.001$) and positively augmented muscle hypertrophy in resistance-trained young adult men. The research supports a positive outcome of consuming creatine in recreational athletes.

Bodybuilders have a favorable outcome on muscle mass while taking creatine. However, there were only two studies located that presented data to show improvements in bodybuilders who take creatine. Jovanov et al (2019) showed a significant ($p < 0.05$) improvement with a 40% strength increase allocated to muscle hypertrophy with creatine. Stecker et al (2019) provided a greater ($p < 0.05$) increase in lean muscle mass and 1-RM strength in the creatine monohydrate group. Both studies demonstrated exceptional results. Nonetheless, there is a need for more research on the subject to determine the future use of creatine in bodybuilders.

In the Journal of the International Society of Sports Nutrition (Antonio et al., 2021), creatine uses in athletes and exercising individuals showed improvements in muscle mass, performance, and recovery. Furthermore, creatine ingestion increases muscle strength and shows increased lean body mass noted by the Gatorade Sports Science Institute (Dawson, 2018).

The Academy of Nutrition and Dietetics Evidence Analysis Library published a grading table to use in all studies with a rating based on the Quality Criteria Checklist (QCC) for Primary Research (Academy of Nutrition and Dietetics, 2016). Based on the quality and quantity of studies, the authors identified the research evidence and conclusion of this systematic review as 'Fair' quality. The studies overall presented a "+" rating with strong quality primary research ($n = 31$). There were no negative studies presented, however, there were two studies that showed no significant outcomes ($n = 2$). Two major strengths of the studies included significant p-values and results from authors. In conclusion, the quality of the studies resulted in a favorable rating of this review.

5. Strengths and Limitations

The strength of this systematic review lies in its inclusion of studies from diverse regions, such as the United States, Australia, Mexico, and the United Kingdom. The studies generally demonstrated a strong methodology with well-defined inclusion and exclusion criteria. However, the review also had limitations. Several studies featured small sample sizes, and some included athletes or recreational participants outside the age requirements. Additionally, certain studies lacked clarity regarding inclusion and exclusion criteria, while others did not provide robust evidence. Furthermore, many studies reported biases, including inconsistent measurement outcomes related to creatine use.

6. Application for Practitioner

Research has shown creatine is safe and effective when ingesting 5g/day before, during, or after team sports, physical activity, and/or resistance training. Creatine has helped improve muscle hypertrophy/muscle mass in different types of athletes such as sports athletes and recreational athletes. Even though there were limited studies to suggest creatine in the use of bodybuilders, the results did show a positive output on strength and lean muscle mass.

7. Conclusion

The research presented beneficial muscle hypertrophy results in athletes consuming creatine. Athletes and recreational athletes, who participate in team sports and resistance training, showed improvements in muscle hypertrophy and/or muscle mass with the use of creatine. The effects of ingesting creatine in different types of athletes presented some positive outcomes in different aspects including one-rep max, strength, and lean body mass. Furthermore, additional research in the study of creatine is warranted. There is a need for larger-scale, long-term studies to establish whether there is a safe, daily creatine dosage. In addition, future research needs to include different athletic groups.

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Authors' contributions

LD and KH were responsible for the study design and revising. LD was responsible for data collection. LD drafted the manuscript, and KH revised the various drafts. All authors read and approved the final manuscript.

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The Publication Ethics Committee of the Macrothink Institute.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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Glossary

LOAD: Loading Phase

MM: Muscle Mass

PRE: Preloading

RCT: Randomized Controlled Trials

RT: Resistance Training

TRAD: Traditional Resistance Training

1RM: 1 Repetition Max