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# Additional Benefits of Creatine Monohydrate Supplementation on Muscle Strength, Muscle Mass Gain and Training Performance - A Systematic Review

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## ABSTRACT

**Introduction:** Creatine monohydrate is one of the most researched and tested supplements in sport known for its benefits on muscle strength, muscle mass gain and training performance. This systematic review synthesizes evidence from various studies to evaluate the impact of creatine monohydrate supplementation on the following outcomes.

**Aim of the study:** To assess the effects of creatine monohydrate supplementation on muscle strength, muscle mass gain and training performance by summarizing evidence from case studies, clinical trials and long term research.

**State of knowledge:** Studies confirm that creatine monohydrate supplementation effectively enhances athletic performance, accelerates recovery, increases muscle strength and muscle mass gain. Additionally, it offers therapeutic advantages for neurodegenerative diseases, type 2 diabetes, aging and various chronic conditions.

**Material and methods:** A review and analysis of randomized clinical trials and clinical studies from 2017 to 2025 available in PubMed.

**Conclusions:** Research findings indicate that long term creatine monohydrate supplementation demonstrates a positive impact on muscle strength, muscle mass gain and training performance. The evidence suggests that creatine enhances strength and hypertrophy of the muscle fibers, improves recovery, exercise capacity and high-intensity performance. These benefits make creatine monohydrate a valuable, safe and well-researched supplement for professional and amateur athletes, regardless of age and gender.
**Keywords:** creatine in sport, creatine monohydrate, creatine supplementation, muscle adaptation, athletic performance

## 1. INTRODUCTION

### 1.1 Creatine – a compound naturally occurring in the human body

Creatine is an organic compound primarily synthesized in the liver, kidneys and pancreas at an approximate rate of 1 gram per day through an interorgan metabolic process. Its endogenous production occurs in two enzymatically regulated steps involving the amino acids glycine and arginine. The first step is catalyzed by L-glycine-arginine amidinotransferase (AGAT) while the second is facilitated by guanidinoacetate methyltransferase (GAMT) [1]. Both the endogenously synthesized creatine and that acquired from dietary sources (such as meat and fish) are transported through the bloodstream and absorbed into tissues via creatine transporters. Upon entering the cells about two-thirds of creatine undergoes phosphorylation by creatine kinase (CK) to form phosphocreatine (PCr) while the remaining creatine is available for further phosphorylation [2]. Creatine exists in the human body in two forms: phosphorylated and free. Approximately 95% of the body's creatine reserves are localized within skeletal muscle where it serves a crucial function in adenosine triphosphate (ATP) synthesis through the phosphocreatine shuttle mechanism. The remaining 5% is distributed across various tissues including the brain, liver, kidneys and testes [3]. Due to their relatively low molecular weight and minimal charge creatine and phosphocreatine are crucial for the effective resynthesis of adenosine triphosphate during energy metabolism through the phosphagen or creatine

kinase/phosphocreatine (CK/PCr) system. The CK/PCr system is the most important element of muscle bioenergetics during high-intensity exercise [2]. Intramuscular creatine concentrations exhibit considerable individual variation which is influenced by factors including diet, sex, age and genetic predisposition. For instance, vegetarians typically possess lower muscle creatine levels compared to individuals who consume meat or fish. Moreover, women generally display lower levels of muscle creatine than men [1]. In skeletal muscle creatine and phosphocreatine are degraded non-enzymatically to creatinine which is transported into the bloodstream and excreted via urine. Healthy kidneys filter creatinine to prevent its accumulation in the blood [4].

Although creatine is naturally found in animal-derived foods, supplementation provides a more practical, efficient and consistent method for enhancing creatine intake. This is due to the fact that creatine supplements offer higher dosages, more rapid absorption and greater control over intake, making them significantly more effective than dietary sources alone [1].

### 1.2 Creatine monohydrate - popular sport supplement

Since the early 1990s creatine monohydrate (CrM) powder has been the most widely researched and frequently utilized form of creatine among various dietary supplements [4]. The majority of studies highlighting the efficacy of creatine supplementation have used creatine monohydrate [5]. Creatine has become widely recognized as a dietary supplement due to its essential role in human health and physical performance. Numerous studies conducted over the past few decades have demonstrated that creatine supplementation exerts significant beneficial effects on skeletal muscle structure and metabolism including the enhancement of training volume and muscle mass growth or hypertrophy in combination with exercise [6].

Creatine monohydrate is the preferred form of creatine supplementation due to its superior bioavailability, effectiveness in elevating creatine concentrations within muscle and other tissues, well-documented safety profile when used correctly and comparatively lower cost relative to alternative forms, such as creatine ethyl ester and creatine hydrochloride [1]. Research has demonstrated that creatine monohydrate supplementation results in significant improvements in muscular strength, lean body mass and muscular endurance following a period of resistance training and other forms of high-intensity exercise in both younger and older adults [5]. Several mechanisms have been suggested to account for CrM's positive effects on training-induced adaptations including an enhanced protein expression and synthesis, modifications in myogenic transcription factors and heightened mitotic activity of satellite cells [7].

Approximately 99% of consumed creatine monohydrate is absorbed into the bloodstream subsequently being transported into muscle tissue or excreted through urine [4]. Oral administration of high doses of creatine has been demonstrated to substantially elevate total muscle creatine concentrations. Several factors can modulate tissue responsiveness to creatine supplementation including baseline intramuscular creatine content, muscle fiber composition and habitual dietary creatine intake [3]. Creatine monohydrate powder demonstrates significant stability exhibiting no indication of degradation into creatinine over extended periods even under elevated storage temperatures [4].

The safety profile of creatine supplementation has been extensively examined. When administered appropriately both short-term and long-term creatine monohydrate supplementation (up to 30 g per day for a duration of five years) has been deemed safe and well-tolerated among healthy individuals [3]. Creatine as a sport supplement is not banned by the International Olympic Committee, the World Anti-Doping Agency or the National Collegiate Athletic Association [3].

### 1.3 Methods of creatine monohydrate oral administration

Supplementation with creatine monohydrate during training (e.g., 5–25 g/day for a duration of 4–12 weeks) has been shown to enhance increases in muscle mass, strength and exercise performance [4]. One of the most popular creatine monohydrate supplementation protocols consists of an initial loading phase of 0.3 g/kg/day for a duration of 5 to 7 days, followed by a maintenance phase of 0.03 g/kg/day, typically sustained for 4 to 6 weeks [1]. Additionally, several studies have reported increases in muscle mass and strength following creatine loading protocols typically involving a daily intake of 20 g for approximately one week followed by a maintenance dose of 2–3 g per day. However, the loading phase may not be essential, as muscle creatine saturation is achieved through a daily intake of 3 g of creatine monohydrate over 28 days [8].

### 1.4 The health benefits of creatine monohydrate supplementation

Supplementation with creatine monohydrate has demonstrated not only favorable impacts on exercise performance and training adaptations but also several potential therapeutic benefits for children and adolescents [2]. Chronic creatine supplementation when combined with moderate-intensity resistance and endurance training is likely to mitigate oxidative stress and enhance the body's antioxidant defense mechanisms. The reduction of the oxidative stress has been evidenced by a reduction in lipid peroxidation in plasma, heart and liver tissues and the gastrocnemius muscle [9]. Numerous studies have indicated a decrease in CK levels, DOMS,

inflammation and oxidative stress alongside an enhancement in muscle strength in individuals supplementing CrM, following a single session of intense exercise when compared to those receiving a placebo within 24–48 hours post-exercise [7].

Creatine supplementation when paired with resistance training in elderly populations has shown positive effects on muscle mass, strength, physical performance and bone mineral density in older adults. However, without resistance training creatine supplementation may require up to two or more years to yield potential muscular benefits in older individuals. Furthermore, creatine supplementation alone does not seem to impact bone mineral density [3]. The combined use of creatine monohydrate supplementation and resistance training offers a promising strategy for older adults as it enhances indicators of lean body mass, limb muscle thickness, muscular strength (in both the upper and lower body) and overall functional capacity. Moreover, emerging evidence suggests that creatine, whether obtained through supplementation or dietary intake may contribute to improvements in certain aspects of cognitive function. Additionally, creatine monohydrate supplementation appears to confer protective effects against sarcopenia in aging populations [10].

Creatine supplementation seems to be a rational strategy for addressing certain nutritional challenges linked to vegetarian diets. Since vegetarians exclude animal products from their diet, they may experience significant improvements in performance and recovery through creatine supplementation [11].

## 2. MATERIALS AND METHODS

PubMed databases were searched using appropriate keywords for accessible studies published until April 2025. Only articles written in English were included. Titles and abstracts were screened first, followed by an evaluation of relevant full-text publications.

## 3. DISCUSSION

### 3.1 Effect on muscle strength - literature review

Creatine (Cr) supplementation has demonstrated a beneficial impact on muscle strength, athletic performance and muscle hypertrophy across all healthy young individuals, including those, who were untrained [12]. Multiple evidence strongly supports the beneficial effects of creatine supplementation particularly in enhancing upper and lower body strength, improving performance in high-intensity anaerobic activities [11]. The majority of the studies have indicated that creatine supplementation serves an effective ergogenic aid for enhancing muscular strength and power. These findings have been observed across diverse populations including both trained and untrained individuals, as well as athletes and non-athletes of both

sexes. The primary mechanism underlying the ergogenic effects of creatine supplementation is largely attributed to an increase in intramuscular phosphocreatine (PCr) concentrations [13]. Experienced powerlifters supplementing with creatine demonstrated greater improvements in three-repetition maximum (3 RM) bench press performance compared to those receiving a placebo over a 26-day training period. Additionally, the creatine-supplemented group completed a higher total number of repetitions at 85% of their 3 RM than the placebo group [13].

CrM supplementation has been shown to enhance strength gains during resistance training (RT). After two weeks of training participants in the Cr group exhibited significantly greater strength improvements compared to the placebo group in three out of six exercises (bench press, leg press and shoulder press). By the conclusion of the eight-week training period strength remained significantly higher in the Cr group for four of the six exercises (bench press, leg press, shoulder press and triceps extension) whereas no significant differences were observed for the biceps curl or lat-pulldown. These findings suggest that Cr supplementation can lead to measurable increases in muscular strength within two weeks of resistance training [14]. Following a 10-week study combining resistance training (including leg extension and leg curl machine, barbell bench press, lateral pulldown, barbell curl, overhead press and triceps extension machine) and creatine monohydrate supplementation the training-placebo group exhibited an average muscle strength increase of 35.9%, whereas the training-creatine group demonstrated a greater increase of 57%. These findings highlight the overall beneficial impact of resistance training on muscle strength in older adults while also emphasizing the synergistic effects of creatine monohydrate supplementation in further enhancing strength gains. Additionally, the results indicated improvements in the quality-of-life index of 79.9% in the training-placebo group and 89.2% in the training-creatine group. The incorporation of CrM supplementation alongside resistance training has the potential to double the strength gains achieved through resistance training alone [9]. Significant enhancements in average anaerobic power during the Wingate test, as well as increased back squat strength have been observed following a five-day creatine supplementation protocol in conjunction with resistance training. Notably, these benefits were not observed after only two days of creatine loading, suggesting that a loading period exceeding two days may be necessary to achieve meaningful improvements in strength and power when combined with resistance training. Short-term benefits of creatine supplementation have also been documented in young adult males with no prior experience in resistance training. Following a 10-day supplementation period, significant

improvements were observed in bench press and squat strength. Additionally, these enhancements occurred despite the absence of a structured resistance training program during supplementation, indicating the ergogenic potential of creatine [13]. In 22 identified studies it was indicated that the average increase in muscle strength (measured as 1, 3 or 10 repetition maximum) was approximately 8% greater during resistance training with creatine supplementation than throughout RT alone [13].

Another study has also reported significant increases in fat-free mass and handgrip strength among 30 pediatric patients with Duchenne muscular dystrophy following a four-month period of creatine supplementation. Notably, the supplementation regimen was well tolerated and did not negatively impact laboratory markers associated with kidney function, oxidative stress or bone health [4]. Furthermore, after creatine supplementation a notable increase in strength was observed in 12 boys with Duchenne muscular dystrophy and 3 boys with Becker's muscular dystrophy. Additionally, the time to exhaustion during a submaximal contraction nearly doubled [6].

### 3.2 Effect on muscle mass gain - literature review

The effects of creatine supplementation have been widely investigated in both athletes and healthy individuals. In addition to its role in enhancing muscular performance, creatine supplementation contributes to an increase in body mass by promoting fat-free mass gains while simultaneously lowering body fat percentage. These changes in body composition are more pronounced when creatine intake is paired with resistance training [1]. When incorporated into a resistance training regimen creatine supplementation enhances an athlete's capacity to train at higher intensities, thereby facilitating more significant training adaptations and ultimately promoting greater anabolic improvements [11]. Creatine supplementation seems to be more beneficial for muscle growth in healthy young individuals compared to other demographic groups [12]. In research involving young adults creatine supplementation even without a loading phase demonstrated a positive impact on muscle mass, athletic performance and muscle strength within a two-week period [12].

Creatine monohydrate has the potential to enhance protein synthesis. Discussed supplement may improve muscle glycogen storage by stimulating AMP-activated protein kinase (AMPK) phosphorylation which subsequently promotes GLUT4 translocation. Moreover, CrM can further stimulate protein synthesis by upregulating the myogenic transcription factor MRF-4, thereby facilitating the differentiation of satellite cells into myonuclei [15].

The observed increase in lean body mass is partially attributed to elevated water retention within muscle tissue. It has been proposed that the resultant rise in osmotic pressure, due to increased creatine content induces muscle cell swelling which is recognized as a critical factor in stimulating cellular growth [12]. The majority of studies have observed an increase in body weight following creatine supplementation, although this finding remains unverified by certain investigations. These weight changes may, at least partially, be explained by a positive nitrogen balance which leads to an elevation in protein synthesis. However, this hypothesis seems more valid when Cr supplementation is extended over longer durations and accompanied by resistance training regimens [16].

Creatine supplementation has the potential to enhance the adaptive response by regulating the upregulation of various growth factors such as myogenin, MRF-4 and insulin-like growth factors I and II (IGF-I and IGF-II). Additionally, the combination of creatine intake and resistance training has been shown to increase both the number of satellite cells and the concentration of myonuclei to a greater extent than resistance training alone. The elevation of muscle creatine content through supplementation facilitates the expression of multiple genes involved in adaptive processes including osmosensing, cytoskeletal remodeling, GLUT4 translocation, glycogen and protein synthesis, satellite cell proliferation and differentiation, DNA replication and repair, mRNA processing and transcription and cell survival. Some of these adaptations may be influenced by increased intramuscular water content which can reduce protein degradation and RNA breakdown while promoting the synthesis of proteins, DNA and RNA [17]. In addition to its potential anabolic effects creatine supplementation may also exhibit anti-catabolic properties [13].

### 3.3 Effect on training performance - literature review

Multiple studies demonstrated that prolonged creatine supplementation when combined with strength and conditioning training programs led to enhancements in various measures of strength, power and body composition. These results have been related to numerous sports disciplines (for example: track sprints, swim sprints, pursuit cycling, field hockey, american football, ice hockey, combat sports, water sports, soccer, tennis, team handball, rugby, bodybuilding, powerlifting) [13]. Regardless of the population, training intervention or supplementation protocol creatine monohydrate supplementation has consistently been shown to enhance strength and power performance during short-duration activities. Consequently, creatine supplementation is widely utilized by athletes across various sports disciplines including team sports such as football, soccer, basketball and volleyball [2]. Substantial

evidence indicates that supplementation with creatine monohydrate can improve performance in short-duration, high-intensity exercise among athletes [18]. The ability of creatine to enhance multiple aspects of exercise performance is extensively supported by scientific evidence. The extent of this performance improvement is influenced by numerous factors including the supplementation protocol, the athlete's training status and various exercise parameters such as exercise intensity and duration. A review of the relevant literature indicates that performance enhancements of approximately 10%–15% are commonly reported [13].

For numerous athletes and coaches the primary concern regarding creatine supplementation is its effect on sports performance. Extensive research has demonstrated that creatine supplementation increases intramuscular PCr levels, accelerates ATP resynthesis and enhances performance in short-duration, primarily anaerobic, intermittent exercise. Given these documented advantages it has been proposed that creatine supplementation may contribute to improved competitive performance in athletic settings [13]. The literature provides substantial evidence supporting the efficacy of creatine supplementation in enhancing anaerobic performance particularly emphasizing its most significant effects on short-duration (<30 seconds), high-intensity, intermittent exercises. The performance benefits of creatine supplementation are most commonly and consistently observed in weightlifters and bodybuilders, whose training relies on brief, maximal efforts and the development of lean body mass. Additionally, improvements in performance have been noted in short-distance running, jumping, throwing and combined track and field events with creatine supplementation [3].

Creatine supplementation in conjunction with resistance training significantly enhances both upper and lower body muscle strength compared to resistance training alone in healthy individuals under 50 years of age. The findings indicate that 4 to 12 weeks of creatine supplementation (ranging from 2 to 10 g/day or 0.03 to 0.22 g/kg/day) combined with resistance training, leads to a significant increase in upper body strength by 4.43 kg and lower body strength by 11.35 kg when compared to resistance training alone. Additionally, the benefits of combining creatine supplementation with resistance training appear to be more pronounced in males than in females [19]. Cr supplementation enhances muscle performance by augmenting PCr stores and accelerating the resynthesis of ATP through the ATP-PCr system. This leads to an increase in strength and the volume of work performed during repeated efforts, such as resistance training, resulting in a greater stimulus for muscle hypertrophy [20].

Significant enhancements in fat-free mass, bone-free mass, training volume and sprint performance were observed among NCAA Division I collegiate football players after 28 days

of creatine supplementation combined with a resistance and agility training program. Likewise, after five weeks of creatine supplementation, freshman and redshirt collegiate football players in the United States demonstrated greater improvements in bench press and squat performance, as well as lower body power, compared to those receiving a placebo [13]. Collegiate redshirt football players who supplemented with creatine demonstrated significantly greater enhancements in one-repetition maximum (1RM) strength in the bench press and back squat, as well as improved anaerobic capacity, compared to those who engaged in training without supplementation. Similarly, after participating in a 10-week strength and conditioning program, collegiate football players who consumed a low daily dose of creatine monohydrate (5 g/day) demonstrated significantly greater improvements in maximal performance on the bench press and squat compared to training groups without CrM supplementation. This study was particularly noteworthy, as it not only confirmed the potential of creatine supplementation to enhance strength and power, but also indicated that a loading phase was not required to achieve these benefits. Similar advantages have been documented among female collegiate athletes who incorporate creatine supplementation alongside a structured strength and conditioning regimen. In a study involving female collegiate lacrosse players engaged in a concurrent resistance training program during a five-week preseason conditioning period, those who supplemented with creatine exhibited superior strength improvements compared to the placebo group. Likewise, during a 13-week resistance training program female collegiate soccer players who consumed creatine demonstrated significantly greater strength gains in the back squat between weeks five and thirteen than their counterparts receiving a placebo [13]. The current findings suggest that low-dose, short-term oral creatine monohydrate supplementation (0.03 g/kg/day for 14 days) positively influenced muscle power output in young soccer players without any negative side effects. Creatine monohydrate enhances the capacity to produce greater power during high-intensity exercise and its supplementation may enable athletes to train at higher intensities, thereby promoting adaptive responses in skeletal muscle to exercises [16]. Creatine monohydrate supplementation enhanced strength-training adaptations and sports performance in U16 basketball players participating in a combined resistance and plyometric training regimen. Specifically, CrM supplementation led to an improvement in power output in one of four power tests and an increase in points scored per game in this U16 group [2]. Short-term supplementation with creatine, beta-alanine, and L-citrulline (individually or in combination) during sport-specific interval training (SSIT) has been shown to significantly enhance the physical and physiological performance of basketball players compared to placebo groups [21]. Creatine monohydrate plays a dominant role during a 15-second maximal sprint. In a placebo-

controlled crossover study 20 male and 5 female cyclists participated in four laboratory sessions. Following an initial familiarization trial baseline data were collected. Participants received a placebo (4 × 5 g/day of maltodextrin) or creatine monohydrate (4 × 5 g/day) for five days prior to each test session. Supplementation with CrM resulted in significant enhancements in both 15-second sprint performance and FFM compared to baseline and placebo groups [22]. The effect of creatine supplementation on swimming performance is negligible and does not reach statistical significance, indicating that it is unlikely to serve as an effective performance enhancer in swimming [23]. Research has indicated that creatine may influence thermoregulatory processes by preserving erythrocyte osmotic stability and enhancing sweat production, thereby contributing to improved exercise performance in hot and/or humid environments [24]. Cr supplementation has been increasingly recognized as a potential strategy for mitigating the deterioration in cognitive function caused by sleep deprivation in athletes. Following 24 hours of sleep deprivation creatine supplementation has been found to attenuate performance impairments in reaction time, mood and balance. Recent studies indicate that a single high dose of creatine (0.35 g/kg) may partially counteract metabolic disruptions and cognitive decline associated with fatigue induced by sleep loss [25].

In females, creatine monohydrate supplementation appears to exert a clinically significant impact on certain performance outcomes particularly during the high-hormone phase. The evidence suggests that creatine monohydrate may mitigate declines in sprint performance associated with this phase [26]. Despite this the evidence regarding the effects of creatine supplementation on athletic performance in females still remains inconclusive. While certain studies have reported performance improvements in specific outcomes the majority have found no significant advantage over placebo groups [27]. In women who have undergone bariatric surgery, pre-exercise creatine supplementation during strength training does not offer greater benefits than placebo in reducing body weight and fat mass or in preventing muscle mass loss during the early stages of postoperative rehabilitation [28, 29].

Creatine supplementation has the potential to enhance performance in both vegetarians and omnivores. Several factors may affect the efficacy of creatine supplementation including the total creatine storage and the duration of an individual's vegetarian diet. Creatine supplementation may be particularly beneficial for stricter vegetarians, such as vegans, as their creatine stores tend to be lower leading to more significant increases in creatine levels with supplementation [11]. Considering that Cr and PCr concentrations are generally reduced in the muscles of vegetarians and vegans, supplementation with creatine may provide considerable

advantages by elevating these concentrations and potentially enhancing exercise performance and recovery. Therefore, for individuals following vegan or vegetarian diets and aiming to improve high-intensity exercise performance or recovery creatine supplementation represents a promising approach particularly due to their typically lower baseline muscle creatine levels [1].

The supplementation of creatine monohydrate did not result in any adverse effects and, as anticipated, contributed to an enhancement in performance and an increase in body weight. No alterations were detected in red blood cell parameters, white blood cell profiles, blood lipid profiles, metabolic and urinary markers or hepatic and renal function within the supplemented group. Although weight gain was an expected outcome, creatine monohydrate supplementation was deemed safe for health with no harmful effects observed on various organs or physiological systems [30]. The safety and practicality of Cr supplementation in patients with prostate cancer have been demonstrated with no supplementation-related adverse events reported [31].

The demonstrated effectiveness of creatine monohydrate prompted its widespread adoption among elite athletes, signifying a pivotal development in the field of sports nutrition. Its broader significance and long-lasting influence continue to affect both athletic enhancement and clinical applications [32].

## 5. CONCLUSIONS

The studies discussed above provide compelling evidence that creatine monohydrate supplementation offers significant, additional benefits in enhancing muscle strength, promoting fat-free muscle mass gain and improving overall training performance, specifically when combined with resistance training. These results are well-supported by the literature over several decades. Across multiple studies and research, CrM supplementation has been shown to amplify the physiological adaptations induced by resistance training leading to superior improvements in maximal strength, power output and endurance capacity. Notably, these benefits extend to both untrained individuals and experienced athletes, indicating that creatine's ergogenic effects are applicable across various training backgrounds. The most important mechanism underlying these benefits is creatine's role in increasing intramuscular phosphocreatine stores which facilitates rapid ATP resynthesis during high-intensity exercises. This enhanced energy availability supports greater training volume, reduced muscle fatigue and improved recovery between training sets, ultimately contributing to superior gains in muscle strength and hypertrophy. Additionally, creatine supplementation has been linked to increased satellite cell activation, myonuclear accretion and muscle protein synthesis, all of which are

crucial for muscle fibers growth and muscle cells adaptation. These findings highlight the potential of creatine monohydrate not only as an acute performance-enhancing supplement but also as a long-term aid in optimizing muscle development. Creatine monohydrate remains one of the most effective and well-researched dietary supplements available for athletes. Various studies support the safety and tolerability of creatine supplementation with no adverse effects in healthy individuals. Moreover, creatine monohydrate is not an anabolic steroid but rather a naturally occurring compound that is legally available as a dietary supplement. It is not classified as a banned substance by major anti-doping organizations and is widely accepted for use in various sport disciplines. CrM ability to augment resistance training adaptations, enhance recovery and support muscle hypertrophy makes this supplement a valuable tool for professional athletes and recreational lifters, regardless of their age and gender.

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Authors do not report any disclosures.

## Author's contributions

Conceptualization: TK, ŁK;

Methodology: TK, ŁK;

Software: n/a; check: TK, ŁK, MB;

Formal analysis: ŁK, MB;

Investigation: TK, ŁK, MB, MP, KM;

Resources: TK;

Data curation: TK, ŁK, MB, MP, KM, PZ, JM, AC, AJ, MK;

Writing - rough preparation: TK, ŁK, MB;

Writing - review and editing: TK, ŁK, MB, MP, KM, PZ, JM, AC, AJ, MK;

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