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Effects of creatine on strength, muscle mass, post-exercise recovery and anaerobic capacity in women - literature review

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Abstract

Introduction:

Creatine is one of the most commonly used ergogenic supplements in sport and physical activity. Its primary role is associated with energy metabolism through increasing phosphocreatine stores and supporting rapid ATP resynthesis. Although the effects of creatine supplementation have been extensively studied in men, increasing attention is currently being paid to its influence on women, especially regarding muscle strength, muscle mass, post-exercise recovery, and anaerobic performance.

Materials and methods:

This study is a narrative literature review based on the analysis of scientific articles concerning creatine supplementation in women. The reviewed studies included physically active women, athletes, and older women participating in resistance or high-intensity exercise programs. Meta-analyses, systematic reviews, randomized control trials, systematic and literature reviews, from past 18 years were analyzed.

Aim of the study:

The aim of this study was to evaluate the effects of creatine supplementation in women, with particular emphasis on muscle strength, muscle mass, post-exercise recovery, and anaerobic performance.

Conclusions:

In summary, the available data suggest that creatine supplementation may benefit women in terms of muscle strength and anaerobic performance, particularly when combined with regular training. The effects on muscle mass gain and post-workout recovery remain less conclusive. Despite the growing number of studies, there is still a need for further, well-designed research involving women to more accurately determine the effects of creatine depending on age, physical activity level, and hormonal changes.

Keywords:

creatine supplementation; women; muscle strength; muscle mass; post-exercise recovery; anaerobic performance; ergogenic aids

1. Introduction

Creatine is one of the most well-researched and widely used supplements in sports. This compound plays a key role in the body's energy metabolism by participating in the rapid resynthesis of ATP during high-intensity exercise. By increasing phosphocreatine stores in the muscles, creatine can help improve exercise capacity, increase muscle strength, delay fatigue, and support recovery processes. For this reason, creatine supplementation is commonly used by both elite and recreational athletes.

Despite many years of research into the effectiveness of creatine, the vast majority of these studies have been conducted primarily on male populations. In recent years, however, increasing attention has been paid to the physiological and hormonal differences between the sexes. These biological differences may influence creatine metabolism and the body's response to supplementation. Research suggests that women may differ, among other things, in their

baseline creatine stores, their response to physical activity, and their post-exercise recovery process.

Creatine supplementation in women is of interest not only in the context of improving athletic performance but also in supporting health and overall fitness. Particular attention is paid to its effects on muscle strength, muscle mass, anaerobic capacity, and post-exercise recovery. Meanwhile, research findings remain somewhat inconclusive, and the number of studies focusing exclusively on women remains limited.

The aim of this study was to analyze the current state of knowledge regarding the effects of creatine supplementation in women. The study discusses the characteristics of creatine, its metabolism, and its functions in the body, and then analyzes the effects of supplementation on muscle strength, muscle mass, post-exercise recovery, and anaerobic capacity in women.

2. Characteristics of Creatine

2.1 Chemical Structure and Metabolism

Creatine (N-aminoiminomethyl-N-methylglycine) is a nitrogenous organic compound that plays a key role in the body's energy metabolism. Endogenous production occurs mainly in the liver, kidneys, and pancreas, resulting in the production of approximately 1 gram of creatine per day, which accounts for half of the daily requirement; the rest is obtained from the diet [1,2]. Creatine is found primarily in animal-based foods such as meat and fish [3].

2.2 Endogenous Synthesis and Storage

Creatine consists of three amino acids: glycine, arginine, and methionine. Its synthesis occurs in two stages [2]. In the first stage, which takes place mainly in the kidneys, the enzyme L-glycine-arginine amidinotransferase (AGAT) converts glycine and L-arginine into guanidinoacetate. Subsequently, in the liver, this compound is converted to creatine by guanidinoacetate methyltransferase (GAMT) using S-adenosylmethionine [1,4]. This process can also occur in other tissues, such as the brain or testicles, though to a lesser extent [4]. Creatine synthesis is an energy-intensive process in terms of methyl-group equivalents, which highlights the metabolic importance of this compound [5].

The next step is the transport of creatine via the bloodstream to target tissues, which occurs via a specific SLC6A8 transporter that is dependent on sodium and chloride ions [4,6]. The majority of creatine—as much as 95%—is found in skeletal muscles, while the remainder is distributed to cells and tissues with high energy demands, such as the brain and heart [1,2,4]. The total amount of creatine in a human body weighing approximately 70 kg averages 110–125 g and is closely related to muscle mass [1].

Creatine exists in the body in two forms: one-third as free creatine and two-thirds as phosphocreatine (PCr), which serves as a high-energy reservoir [1,2,5]. The conversion between these forms is catalyzed by the enzyme creatine kinase (CK), which plays a crucial role in maintaining cellular energy balance [1].

2.3 Mechanism of Action of ATP-PCr

Creatine plays a key role in the resynthesis of adenosine triphosphate (ATP). During physical exertion, ATP reserves in cells are depleted, requiring the rapid activation of mechanisms to replenish these stores. The creatine–phosphocreatine (Cr–PCr) system, which operates via a reaction catalyzed by CK, plays a key role in this process. In this reaction, phosphocreatine transfers a high-energy phosphate group to adenosine diphosphate (ADP), rapidly resynthesizing ATP without the need to engage slower metabolic pathways, while being converted into creatine itself [1,2]. The creatine–phosphocreatine system acts as an energy buffer, stabilizing ATP levels and the ATP/ADP ratio within the cell [5].

Creatine also plays a role in what is known as the energy shuttle. It is responsible for transporting high-energy phosphate groups from the mitochondria to the sites of their utilization within the cell [1]. In this way, it ensures a continuous supply of energy to tissues with high or fluctuating energy demands. Additionally, creatine exhibits a protective effect under conditions of metabolic stress by stabilizing the cellular environment and through its antioxidant properties [1,5].

In the body, creatine undergoes a continuous cycle: approximately 1–2% of creatine is converted daily into creatinine, which is then excreted in the urine [1,2]. Therefore, it must be continuously replenished through endogenous synthesis or dietary intake.

3. Creatine as an Ergogenic Supplement

3.1 Effect on Muscle Strength

The most common goal of creatine supplementation is to increase muscle strength. Despite many years and numerous studies, the effect of creatine on strength in women has not yet been thoroughly investigated. Furthermore, its effect depends on the age of the population, the duration of supplementation, and the fitness level of the participants.

A study on untrained women showed that 10 weeks of creatine supplementation combined with strength training leads to 20–25% greater increases in maximum strength in lower-body exercises than resistance training alone [7]. Creatine supplementation also allowed for an increase in training volume, which translated into the ability to lift heavier weights within the same training program [8].

Studies show that both long-term and short-term supplementation can increase strength in both young and older women [7,9]. Additionally, in older women, it has been shown that creatine, combined with resistance training, can counteract age-related losses in strength and fitness and improve muscle function and performance [10,11]. The results of long-term interventions indicate that better effects are achieved with systematic training for at least several weeks [10-12].

The positive effects of creatine supplementation are mainly attributed to an increase in phosphocreatine stores in the muscles, which enables faster ATP resynthesis and increases exercise intensity and training efficiency [7]. This, in turn, leads to greater strength adaptation and better recovery between sets. Another observed effect of creatine is increased recruitment of fast-twitch muscle fibers and enhanced muscle protein synthesis, which indirectly influences strength development [13].

However, not all studies confirm the clear superiority of creatine over a placebo. Some studies indicate no significant differences between supplementation and control groups, particularly in the case of short-term interventions or insufficient training load [7,12,14,15]. Furthermore, meta-analyses suggest that the ergogenic effect in women may be smaller than in men or may not always reach statistical significance, although a trend toward improved strength performance is still observed [15,16].

In summary, despite less compelling evidence than in the male population, creatine supplementation can effectively support the development of muscle strength when used in addition to strength training, particularly in the long term. However, this effect is moderate and depends on the training context and individual physiological factors [10,12,16].

3.2 Effect on Muscle Mass

The effect of creatine on gain in muscle mass depends on the age of the studied population, the duration of supplementation, and the presence of strength training. An increase in fat-free mass (FFM) and a slight increase in muscle mass are most commonly observed, particularly when creatine is used in conjunction with regular strength training [8,17]. As with muscle strength, this mechanism is associated with an increase in PCr stores in the muscles, improved recovery, and an enhanced ability to perform a greater training volume [18].

A study conducted on a population of perimenopausal women showed that long-term supplementation with creatine monohydrate combined with resistance training can lead to a significant increase in FFM and muscle mass. In a study by Aguiar et al., women who took creatine supplements achieved a 3,2% increase in FFM and a 3,7% increase in muscle mass, while changes in the placebo group were minimal. At the same time, no significant changes in

total body weight or body fat were observed in the same study, suggesting that supplementation primarily affects body composition rather than overall body mass. Additionally, the authors highlighted an improvement in daily functioning, manifested by better performance of daily activities requiring muscular strength [8].

Studies conducted on young women reported similar effects. A study on junior women wrestlers showed that short-term creatine supplementation significantly increased muscle hypertrophy in the group of fighters who combined creatine with strength training for 6 weeks, whereas this effect was not observed with training alone [13]. Another study conducted on a group of college dancers involved a six-week creatine supplementation regimen, which increased lean body mass and total body water. The increase in muscle mass was particularly evident in the lower limbs; however, the authors noted that some of the observed changes may have resulted from intracellular water retention, which is a typical effect of creatine supplementation [13,14,19]. At the same time, this study observed a reduction in body fat and visceral fat levels regardless of supplementation, which may indicate that the beneficial effect on body composition stems from the impact of physical activity and dance training alone, rather than from supplementation [14].

It is worth noting that not all studies confirm the positive effect of creatine on muscle hypertrophy in women. A meta-analysis involving older women, despite observing an improvement in muscle strength, did not show a significant effect on muscle mass gain [12]. Another analysis showed no effect on FM and a statistically significant increase in FFM regardless of gender, though the increase was significantly greater in men [18]. Delpino et al. obtained similar results: the increase in LBM in women was small and statistically insignificant compared to the effects observed in men [20]. It has been suggested that the reason for the weaker effects of supplementation in women may be higher baseline creatine concentrations in the muscles, which would limit the potential for further increases in creatine stores during supplementation [8,18].

The nature of the increase in fat-free body mass also remains an important issue. Some authors emphasize that the increase in FFM following creatine supplementation may result not only from muscle fiber hypertrophy but also from an increase in intracellular water [17,19]. A meta-analysis on regional muscle hypertrophy showed that creatine's effect on actual muscle mass gain is relatively small, though statistically significant. This effect was observed in both the upper and lower body, but its practical value was assessed as low [17].

In summary, the available data indicate that creatine supplementation may promote increases in LBM and muscle mass in women, particularly when used in combination with resistance

training [8,17,18]. However, these effects are generally smaller than in men and may be partly due to increased water retention in the body [18,20]. The greatest benefits are observed with long-term supplementation and regular strength training [8,12].

3.3 Effect on Post-Workout Recovery

Post-exercise recovery is also an important aspect of the training process. Research on the effects of creatine supplementation on this process in women remains inconclusive. The literature indicates that creatine supplementation affects: the replenishment of PCr stores and accelerates ATP resynthesis, which may reduce muscle fatigue after intense physical exercise [7,21]. These mechanisms may lead to a faster recovery of exercise capacity and a reduction in symptoms of exercise-induced muscle damage (EIMD) [22,23].

In a study conducted on a group of men and women after 33 days of creatine supplementation, a faster recovery of maximum voluntary contraction (MVC) was observed; MVC was approximately 18.5% higher after 48 hours compared to the placebo group, accompanied by a reduction in perceived muscle fatigue of up to 25%. Furthermore, a reduction in edema was observed, particularly in women, which may suggest a potential gender-dependent effect and an interaction with hormonal factors [24].

Additionally, in a study accounting for phases of the menstrual cycle, creatine was shown to lower the fatigue index, especially during the luteal phase (-5.8% vs. 0.1% in the control group), which may indicate improved resistance to fatigue and indirectly support recovery. At the same time, a trend toward improvement in heart rate variability parameters was observed during the post-exercise period, which may suggest a beneficial effect of supplementation on the body's recovery rate [23].

The specific nature of women's hormonal balance may also be a significant factor modulating regenerative processes. It has been shown that CK activity returns to baseline levels more quickly in women (approx. 48 h) than in men (approx. 72 h) after exercise, which may suggest more efficient repair processes at the cellular level. At the same time, the subjective sensation of muscle soreness (DOMS) may persist longer in women and depend on the phase of the menstrual cycle, indicating the complex nature of recovery and the role of sex hormones in modulating the post-exercise response [25].

In contrast, the results of meta-analyses do not provide clear conclusions but point to significant differences in the assessment of creatine's effectiveness as a recovery aid [22,26]. The first meta-analysis showed that creatine may reduce the severity of EIMD in the short period after intense exercise; however, this effect may be reversed with long-term supplementation [22]. In

contrast, another study emphasized that the available evidence is limited due to the small number of studies, the high heterogeneity of results, and the underrepresentation of women in the analyzed studies[26]. In summary, the available data suggest that creatine supplementation may have a beneficial effect on certain aspects of post-exercise recovery in women, such as reduced fatigue and a faster return of muscle strength [23, 24]. However, the available findings remain inconclusive [22, 26]. Further research is needed, particularly in a group of women, to unequivocally determine the effect of creatine on recovery.

3.4 Impact on Anaerobic Capacity

Another reason athletes choose to take creatine supplements is to improve their anaerobic capacity. Creatine supplementation can have a beneficial effect on performance, particularly during high-intensity, short-duration exercises and in tasks requiring repeated sprints and high muscle power.

Studies conducted on a population of physically active women have shown that creatine monohydrate supplementation can significantly increase anaerobic work capacity (AWC), which is an indicator of the body's anaerobic potential. Eckerson et al. reported a 22% increase in AWC after five days of creatine supplementation at a dose of 20 g per day, while the placebo group showed a decline in performance. Similar results were observed in subsequent studies, where improvements in anaerobic capacity ranged from 10 to 15% following short-term supplementation [7]. These findings suggest that creatine can effectively enhance the ability to perform short-duration, maximum-intensity exercises [27].

The beneficial effects of creatine were also observed in tasks requiring repeated maximum-intensity efforts. Ziegenfuss et al. demonstrated improved performance in cycling sprints among female athletes after just three days of creatine supplementation, and the effect was particularly noticeable during subsequent repetitions of the effort [7]. Ramirez-Campillo et al., however, observed that combining plyometric training with creatine supplementation led to greater improves in jumping ability and the capacity to perform repeated sprints in female soccer players than plyometric training alone [7,28]. This confirms that creatine can enhance the ability to maintain high power output during successive intense anaerobic efforts [27,29].

The beneficial effect of creatine on performance is attributed to an increase in PCr stores in the muscles, which leads to faster ATP regeneration and delays the onset of muscle fatigue. Additionally, creatine supports the buffering of hydrogen ions, thereby limiting the drop in muscle pH during exercise [7,15]. The literature also emphasizes the importance of creatine in reducing fatigue during anaerobic exercise. Studies have shown that supplementation can lower

the fatigue index, particularly in the first phase of the cycle when hormone levels are high [22]. A delay in the onset of neuromuscular fatigue during cycling training was also observed, which was attributed to increased PCr concentrations and lower accumulation of lactate and ammonia in the muscles [7]. As a result, female athletes were able to maintain high exercise intensity for longer [7,29].

However, some studies point to inconclusive results regarding creatine supplementation in women. In a review of 17 studies, only some showed a significant improvement in anaerobic performance compared to placebo [15]. The authors emphasize that these differences may stem from the participants' fitness levels, the duration of supplementation, the type of exercise performed, or the influence of sex hormones [15,29,30]. Despite these discrepancies, most studies suggest that creatine may provide effective ergogenic support in disciplines requiring high power, speed, and repeated anaerobic efforts [7, 27].

In summary, creatine supplementation in women may positively influence anaerobic performance by increasing the ability to perform short-duration, high-intensity exercises, improving power and athletic performance, and delaying muscle fatigue. These effects are particularly evident in activities relying on the phosphagen system and during repeated interval exercises [7, 27]

Discussion

The aim of this study was to evaluate the effects of creatine supplementation in women on muscle strength, muscle mass, post-exercise recovery, and anaerobic capacity. An analysis of available studies indicates that creatine can provide effective ergogenic support not only for men but also for women; however, the effects of supplementation are often less clear for women. This is due both to the smaller number of studies involving women and to physiological differences related, among other things, to hormonal balance, baseline creatine levels, and the phase of the menstrual cycle.

The most consistent results concern the effect of creatine on muscle strength. Most of the analyzed studies demonstrated improvements in strength parameters, particularly when combined with resistance training. These effects were observed in both young and older women, suggesting that creatine may not only support strength development but also counteract age-related declines in physical performance. However, some studies did not show a benefit of creatine over a placebo, especially with short supplementation periods or low training volume. This may indicate that the effectiveness of creatine depends on a properly tailored training program and the duration of supplementation.

When it came to the effect on muscle mass, the results were more inconclusive. Some studies showed an increase in FFM and an improvement in body composition, particularly in women who also engaged in strength training. However, many authors emphasize that the observed increase in FFM may be due in part to increased intracellular water retention, rather than solely to actual muscle hypertrophy. Meta-analyses also suggest that muscle mass gains in women are generally smaller than in men, which may be related to higher baseline creatine concentrations in women's muscles and a different hormonal response.

An analysis of studies on post-exercise recovery indicates that creatine may support post-exercise recovery processes in women, including by reducing perceived fatigue, accelerating the return of muscle strength, and reducing certain markers of muscle damage. Particularly interesting are the results suggesting possible differences based on gender and the phase of the menstrual cycle. Despite promising results from some studies, the scientific literature remains inconsistent and does not allow for clear confirmation of creatine's effectiveness in the context of recovery. Although some studies have shown reduced muscle fatigue and faster recovery in women supplementing with creatine, the available evidence remains limited and is often based on small sample sizes. For this reason, further research is needed involving women with varying levels of physical activity and accounting for the influence of sex hormones.

With regard to anaerobic capacity, most of the analyzed studies confirm the beneficial effect of creatine on the ability to perform short-duration, high-intensity exercises. Improvements in sprint performance, the ability to repeat exercises, and reduced muscle fatigue indicate that creatine may be particularly useful in sports requiring high power and speed. At the same time, the effectiveness of supplementation may depend on the type of exercise, the level of fitness, and the individual's response.

Conclusions

Creatine supplementation can effectively support muscle strength development in women, particularly when combined with regular resistance training and over a longer period of use.

Creatine may contribute to an increase in lean body mass and an improvement in body composition; however, the effects on muscle hypertrophy in women are generally moderate and may be partly due to increased intracellular water retention.

Available studies suggest that creatine supplementation may support post-workout recovery, but the available data are still not sufficiently consistent to draw definitive conclusions.

Creatine has a beneficial effect on women's anaerobic performance, particularly during short-duration, high-intensity exercises that require repeated sprints and high muscle power.

Despite the growing number of studies, there is still a need for further, well-designed research involving women to more accurately determine the effects of creatine depending on age, physical activity level, and hormonal changes.

In summary, the available data suggest that creatine supplementation may benefit women in terms of muscle strength and anaerobic performance, particularly when combined with regular training. The effects on muscle mass gain and post-workout recovery remain less conclusive. Despite the growing number of studies, there is still a need for further, well-designed research involving women to more accurately determine the effects of creatine depending on age, physical activity level, and hormonal changes.

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AI tools were used only to refine the language and improve text readability. The authors retain full accountability for the academic integrity of the work. The conceptual design, literature review, data analysis, and final drafting were executed solely by the authors.

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