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Effect of creatine on improving a person's physical performance: A literature review

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Abstract. Creatine is a popular dietary supplement that has a significant impact on physical performance, strength, and endurance, making it relevant for use in sports, rehabilitation, and performance improvement in different age groups. The purpose of the study was to evaluate the effectiveness of creatine use to improve athletic performance, physical endurance, muscle strength, muscle hypertrophy, and functional performance of athletes, people with physical disabilities, and the elderly. The results of numerous experimental studies were analysed, including controlled trials, systematic reviews, and meta-analyses that evaluated the effects of creatine on a person's physical performance using combined training protocols and various dosing strategies. The conducted studies indicated a high efficiency of creatine use by athletes and people of other professions related to both physical and mental work. It helps to reduce muscle damage and increase the overall performance of athletes, in particular, by increasing phosphocreatine reserves and stimulating anabolic processes. In athletes, creatine helped to increase muscle mass, reduce fatigue, and improve training intensity, regardless of gender. The combination of creatine with other substances has shown additional benefits in increasing strength and endurance. The use of creatine in combination with training contributed to regional muscle hypertrophy, increases their thickness and volume, especially in conditions of restricted blood flow. In older adults, the supplement reduced muscle loss, improved strength and functionality even with low levels of physical activity. Creatine reduced fatigue and improved functional performance in patients with chronic diseases and neurodegenerative conditions. The results poined to the universality of creatine as an effective tool for improving athletic performance, functional performance, and recovery after exercise in various population groups. Its use is recommended for professional athletes, the elderly, and people with special physical needs

Keywords: dietary supplements; sports performance; physical performance; functional efficiency; muscle strength; muscle hypertrophy

Introduction

Creatine is a naturally occurring nitrogen-containing organic compound that plays a key role in muscle energy production during exercise and is an important element of energy metabolism, as it allows rapid regeneration of

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adenosine triphosphate (ATP), supporting muscle performance and endurance. Such properties of creatine are physiologically determined, since the body itself produces and uses this compound for biochemical transformations. It is synthesised in the liver, kidneys, and pancreas from the amino acids arginine, glycine, and methionine, and also enters the body with protein products (meat, fish) or as food additives. Currently, creatine is the most common dietary supplement in the world of sports and modern medicine. The study of this compound opens up new opportunities in its use to increase physical performance, endurance, maintain cognitive health, recover from injuries and loads, and treat various diseases. In the modern world, this is very relevant, since the level of minimum sports standards has significantly increased. The intense rhythm of life and global changes cause stress, anxiety, and nervous disorders, which can be regulated with creatine supplements. In addition, they play an important role in the comprehensive treatment of diseases associated with physical disability and sedentary behaviour, especially among the elderly. Therefore, creatine as a mono-agent, or as part of a complex application, has not only a preventive and energy potential, but also a significant therapeutic effect.

Recent studies of creatine prove its relevance and steady interest of researchers from different countries. Special attention is paid to its application in sports, in particular in dynamic sports such as football, basketball, short-distance running, and weightlifting, where physical processes require a rapid release of energy, since creatine helps to increase the endurance, strength, and speed characteristics of athletes. In particular, the effect of creatine on improving the physical performance of basketball players was investigated by S. Vargas-Molina *et al*. [1], a similar study among weightlifters was conducted by D. Almeida *et al*. [2]. They proved that creatine supplements can increase muscle strength and endurance, without negative effects on health indicators and with minimal side effects. A positive effect was observed on both overall physical performance and strength of the lower and upper extremities. Blood and urine tests for basic biochemical parameters remained normal. Therefore, researchers recommended the use of creatine monohydrate in the sports under consideration.

D. Varillas-Delgado [3] studied the genetic effects on body mass index growth and muscle gain in professional soccer players during and after taking creatine supplements. The experiment involved 161 athletes, each of whom took 20 g/day of creatine for five days, then another seven weeks of 5 g/day. To evaluate the results, the overall genetic profile of the participants was calculated and their anthropometric parameters, in particular, body mass index, muscle and fat mass, were determined. The study found that the increase in muscle mass and body mass index in response to creatine supplementation was most pronounced in athletes who had a genotype associated with increased muscle performance.

A. Gordji-Nejad *et al.* [4] investigated the effect of a single creatine supplement on cognitive function in the brain, in particular, sleep deprivation. According to their research, in people suffering from insomnia or unable to sleep enough hours, a single dose of high-dose creatine orally helped restore metabolic processes in fatigue and cognitive decline. According to the researchers, no side effects were observed, and there were no complaints about the gastrointestinal tract either. Thus, they concluded that even a single dose of creatine can restore the main energy metabolic processes during sleep deprivation in four hours.

B.M. Kious *et al.* [5] studied the possibilities of using creatine in the treatment of neurophysiological disorders. They argued that new strategies for creating antidepressants need to be developed, especially targeting physiological processes that are different from those targeted by conventional treatments. According to current diagnostic and control methods, such as human neuroimaging, genetics, epidemiology, and animal studies, failure in the production, storage, and use of brain energy has been shown to be involved in the development and maintenance of depression. It is creatine, as a dietary supplement, according to their findings, that has prospects for relieving these disorders in patients in the early stages of depression and other diseases in the treatment of which antidepressants are used.

S.M. Ostojic *et al*. [6] studied the effect of creatine on women's reproductive health. Their results proved that supplements of this compound in the diet in the range of 13 mg per kg of body weight per day, throughout a woman's life cycle, provide many potential benefits, contributing to the regularity of the menstrual cycle, the normal functioning of the reproductive system, improving hormonal balance and the ability to ovulate. In particular, cases of oligomenorrhea, the risks of foetal macrosomia in pregnant women, pelvic infections, ovariectomy, and hysterectomy were reduced. The researchers emphasise the need for future studies of the effects of creatine on women at different stages of the menstrual cycle to determine the potential for its use throughout life. Thus, the use of creatine with food of 13 mg per kg of body weight per day significantly reduces the risk of irregular menstruation, pelvic pathologies, and obstetric diseases. However, more research is needed to fully confirm the effect of creatine supplementation on improving reproductive health in women. As a similar study by J. Antonio *et al*. [7] confirmed that an important aspect is that taking creatine does not cause serious side effects if the recommended doses are met.

Research on both the long-term and short-term effects of creatine on the human body opens up new horizons not only in sports, but also in medicine, rehabilitation practice, and preventive use. Improvements in many of the physical parameters that ensure optimal functioning of the human body can be adjusted with the correct use of creatine supplements. The description of positive changes and negative effects during creatine use, physical characteristics in healthy and sick people, athletes and workers, the elderly and people with cognitive disorders will allow understanding more clearly the scale of impact and effectiveness of its use. The purpose of the current study was to investigate the effectiveness of creatine-based

supplements for improving physical performance in various categories of the population, to analyse positive changes, manifestations of side effects, and prospects for use.

To achieve this goal, the most significant and representative scientific articles, meta-analyses, and literature reviews containing quantitative and qualitative data on the effects of creatine on the human body were selected. A comprehensive approach has been applied to search, select, and evaluate research papers. Electronic databases and online libraries were used to search for information: Google Scholar, PubMed, Web of Science, Scopus, Willey, MDPI. The criteria for inclusion in the analysis were: publications with effective conclusions and clear evidence of effectiveness, clear methodological approaches; studies no older than 2014; published in English or Ukrainian; availability of data on the effect of creatine on physical endurance, muscle strength, muscle hypertrophy, functional indicators of the respiratory, nervous, and cardiovascular systems. The exclusion criteria included: papers with unproven effectiveness, insufficiently clear conclusions; older than 10 years; non-compliance with the topic. 43 papers that met the selected criteria were selected. The analysis was carried out in several areas. In particular, the use of creatine to improve the physical capabilities of athletes, the use of this compound in medicine for the treatment of certain clinical conditions and diseases, and the effect of creatine on the physiological parameters of a person, including the elderly.

Use of creatine-based supplements during training and in sports

The efficacy and safety of creatine in the correct dosages explain its popularity as a supplement for optimising physical abilities, improving health, cognitive function, and recovery from hard work or training. More and more people, having learned about the positive properties of creatine, use it as a dietary supplement or include it in the diet of sports nutrition. It is important to understand exactly what physical indicators this supplement improves and whether the result really has such an unsurpassed effect.

The use of creatine-based supplements during intensive training, professional sports gives quite high positive reviews. C. Lanhers *et al.* [8] conducted a meta-analysis of 60 studies on the effects of creatine on the human body under short-term lower limb loads and proved that the use of this supplement improves strength performance during exercises lasting less than 3 minutes, regardless of the characteristics of participants, training protocols, and dosage. The effect of long-term creatine use during training in athletes of various sports was investigated by C.-C. Wang *et al.* [9]. The researchers conducted an experiment during which athletes used creatine supplements for 4 weeks in combination with complex training, which involved performing both anaerobic exercises – in the form of jumps and half-squats, and aerobic – running, complex training. After analysing the blood creatine kinase content and physical performance of athletes, the researchers concluded that the use of creatine supplements helps to reduce muscle damage and has a positive effect on overall athletic performance.

Furthermore, M. Kaviani *et al.* [10] found that creatine intake during strength training is an effective strategy for increasing muscle strength in physically active young adults. In their experiment, they divided 18 participants into two groups: one received creatine during exercise, the other – a placebo. The training programme lasted eight weeks (three days of training per week), with regular strength measurements every two weeks and blood counts 24 and 48 hours after training. The creatine group showed significant improvements in strength in four of the six exercises (triceps extension, leg press, shoulder press, bench press, but no improvements in biceps flexion and deadlift) compared to the placebo group. According to the findings, when creatine monohydrate is added, the increase in muscle strength increases markedly after two weeks of use. However, they note that there was no reduction in muscle damage. Researchers attribute this to excessive training intensity. Similar results for improving training performance and increasing muscle thickness were obtained by R. Sousa-Silva *et al.* [11] and V. Korotych [12]. These observations were also confirmed by a meta-analysis performed by R. Burke *et al.* [13], who claim that the combination of creatine with strength training contributes to regional muscle hypertrophy, which allows purposefully increasing the volume of individual muscle groups. According to the results of their study, the addition of creatine to strength training leads to a significant increase in muscle thickness (average difference of 0.90 mm) and muscle cross-sectional area (average difference of 0.17 cm^2) compared to training without creatine supplementation. The researchers concluded that creatine combined with strength training contributes to more pronounced muscle hypertrophy, especially in the upper extremities. Thus, the claim about the long-term use of creatine to improve physical performance during training of varying intensity is confirmed by a number of experiments and is quite proven.

Creatine use is also common among professional athletes. Researchers conducted experiments involving athletes of various sports to find out whether it is appropriate to use this substance at a professional level. A.P. da Silva Azevedo *et al.* [14] conducted a study of the effect of creatine supplementation on biomechanical parameters during high-intensity interval training (HIIT), accompanied by impact reduction. The experiment involved eight elite football players, who were divided into two groups: one took creatine, the other – placebo. Tests were conducted during HIIT, which included five sessions of exhaustion running. The results showed that creatine supplementation contributed to a higher time to reach the first peak of exhaustion than placebo. There were also significant changes in muscle activation in the initial and intermediate phases. It should be noted that when athletes consumed creatine, there was no effect on heart rate and lactate concentration. According to the results obtained, the researchers note that creatine supplementation can affect the control and strength of impact during high-intensity interval training in football players, and reduce shock and well-being in HIIT.

R. Ramírez-Campillo *et al*. [15] conducted a six-week study on the effects of creatine supplementation on endurance and recovery rate in female football players. Two groups were formed: control and experimental. Athletes were evaluated for maximum and repeated sprint running, speed of change of direction, jumping, and endurance before and after six weeks of training. As a result of research, no noticeable changes were observed in the control group, however in the experimental group, jumping, sprinting, and repeated sprint running improved. These studies support expectations for the positive effects of creatine supplementation on football athletes.

The effect of creatine compounds on the performance of rowers engaged in endurance sports was studied by J. Fernández-Landa *et al.* [16]. The study involved 28 male athletes from the best rowing club of the First Coaching League of Spain. They were divided into four groups: the placebo group, the creatine monohydrate-only group, the β-hydroxy β-methylbutyrate-only group, and the group taking a combination of the two drugs. For 10 weeks, participants took appropriate supplements after training with a chocolate smoothie for recovery, and their athletic performance was assessed using various tests before exhaustion. In addition, the level of lactate was measured, which indicated indicators of exhaustion of athletes. The results showed that combined administration of creatine monohydrate and β-hydroxy β-methylbutyrate resulted in a synergistic improvement in aerobic capacity associated with individual lactate thresholds, whereas individual administration of these supplements did not have such an effect. Researchers explain this by various physiological mechanisms of influence on the body's energy assets.

S.J. Brooks *et al.* [17] investigated changes in dry body weight (excluding fat) after 6 weeks of creatine use by female dancers. According to their research, creatine contributes to an increase in total body water levels and muscle mass, and the amount of visceral adipose tissue has significantly decreased over time. In addition, considering the mental load of female students, a study was conducted on the impact on their mental activity and cognitive functions, but no significant changes were found. According to researchers, such experiments should be conducted during the academic semester, since 6 weeks is a rather limited time to determine these indicators.

S.C. Forbes *et al.* [18] considered the indisputable advantage of creatine to be the ability to reduce inflammatory processes, repair damaged muscle fibres in microtrauma, which allows athletes to recover faster after injuries or intense training. They investigated the effects of creatine in athletes involved in running and jumping, cycling, and skiing. Researchers have found that when exercising for more than three minutes, creatine has good restorative properties, delays the onset of exhaustion, and develops endurance. Researchers explain the positive results by the effect of creatine on such processes as reducing oxidative stress in cells, improving the transport of ATP from mitochondria to recycling sites, improving the kinetic parameters of oxygen, and increasing the buffering of hydrogen ions. In particular, C.R. Soares Freitas Sampaio *et al.* [19] conducted a study involving eight Brazilian paralympic powerlifting athletes aged 23 to 29 years. During the trial, athletes took a placebo for the first 7 days, then a 7-day break, and then 7 days of creatine intake. The results showed that fatigue levels were 16% lower when taking creatine than placebo. The results of maximum torque also improved, while the remaining indicators were similar for both placebo control and creatine. According to researchers, the use of creatine improves strength indicators and reduces the level of fatigue in professional athletes.

Considering the results of research, it is possible to summarise data on the positive effect of creatine supplementation on physical performance during training in professional athletes and people engaged in training in their spare time. It is important to note that no noticeable side effects were detected in the experiments under consideration, with the exception of isolated cases of nausea. All participants in the experiment adhered to the recommended doses of supplements, not exceeding the norm of 3-5 g per day. Also noteworthy is the fact that the effectiveness of creatine is observed with both short-term and long-term use, depending on the expected results.

Creatine use in medical practice

Creatine is widely used in medical practice to support cell energy metabolism, especially in diseases associated with mitochondrial dysfunction. Its use has shown effectiveness in the treatment of neurodegenerative diseases, in particular Parkinson's disease, ALS, and Huntington's disease, as it helps to protect nerve cells from degenerative changes. Creatine is also used in the treatment of a number of diseases of the cardiovascular, respiratory, and nervous systems. In addition, metabolic and cognitive disorders also respond better to treatment when using creatine, especially when combined with other drugs [20].

The effectiveness of creatine use in the treatment of respiratory diseases was studied by F. De Benedetto *et al.* [21]. They showed that patients with chronic obstructive pulmonary disease (COPD) experience improved functional performance when taking creatine together with the antioxidant coenzyme Q. A blind, randomised, placebo-controlled clinical trial involved 108 COPD patients in 9 Italian hospitals. Patients underwent spirometry, a 6-minute walk test (6MWT), bioelectric impedance analysis, and activities of daily living questionnaire (ADL) at the beginning and after 2 months of therapy. 90 patients completed the study in full. Some of them received QTer (coenzyme Q10) and creatine supplements, while others received a placebo. Patients taking the supplements showed improvements of 6MWT (51 ± 69 vs 15 ± 91 m, $p < 0.05$), body cell mass, sodium/potassium ratio, shortness of breath indices, and ADL compared to the placebo group. In the group taking the supplements, the concentration of coenzyme Q10 in plasma increased, while in the placebo group it did not change. Side effects were similar in both groups.

The results showed that in patients with COPD, dietary supplements with CoQ10 and creatine improved functional performance, body structure, and reduced shortness of breath. The systemic increase in some anti-inflammatory metabolites confirms the pathobiological mechanism as the reason for these benefits. Further research is needed to better understand the role of QTer and creatine in COPD patients, the researchers said.

Studies showed that people with type 2 diabetes have altered creatine metabolism and uptake in the body [22, 23]. Therefore, it remains important to determine the dose and duration of creatine supplementation to improve blood glucose control. A. Oskroba *et al.* [24] conducted an experiment on the therapeutic effect of creatine supplementation in patients with type II diabetes mellitus. It was found that the combination of creatine with physical activity significantly reduced glycemic indicators in these patients. Hypoglycemic effects are explained by creatine stimulation of the work of glucose-transmitting protein-4 (GLUT-4), which is insulin-dependent and is responsible for the translocation of glucose into muscle cells to the sarcolemma. Researchers insist on the feasibility of further long-term study, because positive changes in glucose control are very important in the treatment of diabetes.

Another potential therapeutic property of creatine is its ability to support brain function and protect neurons from degenerative changes in diseases such as Parkinson's, Alzheimer's, and amyotrophic lateral sclerosis. Research conducted by C.J. Hass *et al.* [25] proves the positive effect of combining physical activity with creatine supplementation in patients suffering from mild to moderate Parkinson's disease. Participants in the experiment took creatine monohydrate at a dose of 20 g/day. Their exercise results were better compared to the placebo group. Thus, on average, the results improved from 12% to 16%. These studies prove the need to combine physical activity with the use of creatine monohydrate, but require more detailed research. A. Attia *et al.* [26] studied the effect of creatine supplementation on the development of treatment for neurodegenerative disorders. According to researchers, although there are a number of successful clinical experiments on the therapeutic effectiveness of creatine supplements in animals with Parkinson's disease, there are not enough evidence-based modern clinical trials with people with neurodegenerative diseases. Researchers conducted a meta-analysis of the effectiveness of creatine supplementation in people with Parkinson's disease. 1,935 randomised controlled trials were conducted comparing the effects of creatine and placebo on motor activity and quality of life in patients. Unified calculations were performed on the unified Parkinson's disease rating scale (UPDRS). According to their findings, there is no clinically significant evidence for the use of creatine for neuroprotective effects in the treatment of Parkinson's disease. Well-planned randomised controlled trials are needed in the future. Therefore, such studies remain open to determine the optimal protocol for creatine supplementation in the treatment of these diseases.

The effect of creatine supplementation in the complex treatment of cardiovascular diseases, in particular, coronary heart disease, heart failure, or myocardial infarction, is quite relevant, but not yet sufficiently studied. Group of researchers consisting of A. Del Franco *et al.* [27] conducted a meta-analysis and concluded that there was a direct relationship between the creatine content in the heart muscle and the development of heart failure. The researchers attribute this to the fact that creatine, as a component of the energy buffer system, is involved in the metabolism of cardiac activity, contributing to the transmission of a signal from the site of synthesis to the site of use. A decrease in ATP synthesis, the phosphorylation of which depends on the presence of creatine, leads to contractile dysfunction of the heart muscle. Therefore, future research should be aimed at creating protocols for the treatment of patients with heart failure with creatine preparations and determining the optimal doses of creatine.

A. Aron *et al.* [28] conducted a randomised controlled trial on the effect of short-term creatine supplementation on heart and vascular function in older men. For the experiment, men aged 55-80 years were divided into three groups taking creatine, placebo, and a control group. Creatine and placebo were taken for 7 days at a dose of 20 mg per day. Patients were tested on days 1 and 8. The operation of blood vessels was tested using equipment for measuring the pulse wave velocity, and the assessment of cardiac activity was determined by an impedance cardiography device. According to the results of the experiment, the cardio-vascular index had the best indicators in the group taking creatine (8.7 ± 0.5 to 8.2 ± 0.5, $p = 0.03$). There were no changes in the other two groups. The situation was similar with systolic blood pressure, and there was a slight improvement in the creatine group: from 144.0 ± 12.7 mm Hg. up to 136.1 ± 13.4 mm Hg., $p = 0.08$. Stroke volume, ejection fractions, and contractility index were similar in all three groups. Thus, according to the results of the study, the use of creatine for 7 days can have a positive effect on the cardiovascular system, in particular, in heart diseases and atherosclerosis in the elderly. The researchers note that adding creatine to a therapeutic treatment plan is quite effective and safe. Thus, creatine supplements are increasingly used in the complex therapy of rather complex diseases, which allows patients to have a milder course of the disease or recover faster, or have better physical performance.

Effect of creatine on human physiological parameters: general strengthening effects, preventive use

Researchers are actively studying the effect of creatine on human physiological parameters, in particular, its general strengthening effects and the possibility of preventive use. Although most attention is paid to its use in sports and medicine, studies also confirm the benefits of creatine for the elderly, people engaged in heavy physical labour, and patients in the rehabilitation and recovery phase [29-31]. Scientific evidence suggests a positive effect of this compound

on endurance, recovery rate after physical exertion and the body's resistance to stress factors, which makes it a promising tool for a wide range of applications.

K. Elstad *et al.* [32] investigated that in addition to sports achievements, creatine has a positive effect on performance in professions with increased physical activity, in particular in firefighters, which indicates its versatility. The experiment, which lasted 4 weeks, involved 30 male firefighters. The study used carbohydrate and protein supplements for both groups of the experiment, but one also added creatine. The training tests in this study were aimed at evaluating the physical skills needed to effectively perform firefighters' official duties. In particular, they included rescue and forced entry tests that simulated real-world rescue scenarios that required explosive strength, speed, and endurance. An improvement in these indicators in the creatine group indicates its positive effect on explosive power and muscle endurance during short-term but intense physical effort. However, the absence of significant differences between the groups in tests for climbing stairs, moving with a hose, and overall task completion time may indicate that these activities are more dependent on overall aerobic endurance, which is less affected by creatine. Thus, the study confirmed that the combined use of creatine with protein and carbohydrates can improve professional performance in tasks that require short-term maximum physical effort.

K. Prokopidis *et al.* [33] conducted a systematic review and meta-analysis of clinical studies on the effects of creatine on memory in healthy individuals. They summarised the data and concluded that people who consumed creatine as a dietary supplement to the main diet at doses of 2 to 20 g per day improved memory, compared with the placebo groups, by an average of 66%, and in older people (66-76 years) by 83%. Based on the analysed data, researchers claimed that creatine supplementation increases memory processes, especially in the elderly.

People over the age of 65 often have problems not only with memory but also with limited physical abilities. This problem was studied by T.W. Davies [34]. They investigated whether creatine has a positive effect on physical function and mental health in older adults. Because with age, certain physical disabilities can develop, such as muscle weakness, frequent falls, fatigue, limited mobility, which can lead to functional disability and reduced self-care levels. According to the results of the study, researchers found that the use of creatine in general can counteract bioenergetic muscle insufficiency, providing the ability to independently perform functional tasks. This is evidenced by the analysis of the average indicators of the conducted experiments. Thus, in the groups that took creatine supplements, the values of bench press, leg press, and average physical activity tests improved. This is another confirmation of the positive effect of this compound on physical characteristics in the elderly. Similar studies were conducted by V. Seper *et al.* [34]. They noted that creatine affects the physical performance of older adults, in particular, increases muscle strength and endurance. In a pilot project among older participants, it was found that guanidinoacetate-creatine supplements have a positive effect on functional efficiency and improve muscle and brain energy. Various creatine dosing strategies studied by M.J. Chrusch *et al.* [36] also showed a positive effect on physical function, in particular, contributed to slowing age-related loss of muscle mass. An important aspect is that even at an older age, it is possible to achieve significant improvements in physical condition due to the correct use of creatine in combination with physical training. Such studies once again confirmed the hypothesis that creatine can be a useful tool for maintaining an active lifestyle and improving physical function in the elderly, even in people with low fitness levels [37, 38].

The effectiveness of creatine supplements for restoring functional ability after a period of immobilisation of a certain part of the body was also studied. Thus, J.C. Fransen *et al.* [39] conducted an experiment on the rate of recovery of an immobilised limb with and without creatine use. 25 active young people between the ages of 20 and 28 were involved. They performed various exercises on the upper limbs, in the wrist area, after two weeks of immobilisation. In general, the recovery of limb performance in the experimental group had slightly better indicators, but additional research in this area is required. A similar study was conducted by A.P.W. Johnston *et al.* [40], only in their experiment the shoulder joint in young people was immobilised. According to their findings, creatine supplementation helped to maintain muscle mass, elbow flexion strength, and endurance in an immobilised limb.

These studies confirm the prospects of using creatine to stimulate muscle growth, improve physical endurance and strength in various settings, in particular, in people of certain professions, physically active people, people with disabilities and the elderly. Studies show that creatine is the natural energy compound that allows restoring bioenergetic potential in the shortest possible time, with minimal damage to the body. Therefore, when creatine is added as dietary supplements, there are almost no side effects or allergic reactions, with the correct dosage of the drug. Versatility in application, low manufacturing cost – these are other advantages of this compound. The possibility of using creatine compounds in patients and the elderly allows them to be more mobile and feel a surge of strength and the ability to think logically. This effect on the elderly and sick people has been proven experimentally, so this bioactive supplement is increasingly used in medical practice.

M. Balestrino & E. Adriano [41] analysed the results of a large number of studies, and provided evidence for the effectiveness of creatine use in improving the condition of patients with hereditary diseases associated with impaired synthesis of this compound by the body, muscular dystrophy, for the prevention of statin myopathy and certain types of depression in women, and increasing neuropsychic performance. Researchers have confirmed the safety of using creatine in doses up to 20 g per day, with some caveats for people with kidney disease. A similar conclusion was reached by M. Dahal *et al.* [42], who have shown that

creatine is safe and well tolerated by healthy people with both short-and long-term use. In particular, young people who train in gyms both at a professional level and for general strengthening of the body often take creatine supplements as a one-component composition or in combination with proteins, carbohydrates or some B vitamins. Most studies approve of such combinations and prove the effectiveness of their use, in particular, L.U. Schäfer *et al.* [43]. Thus, all the benefits of using creatine to improve physical performance in people of different ages and professional orientation are obvious and experimentally proven.

However, as the analysis of the processed papers has shown, there are still many questions that need to be considered in future research. Researchers explain some inaccuracies in the results or uninformative indicators by the insignificant duration of research or the coverage of a small number of people. The most studied was the effect of creatine on endurance, physical indicators of muscle strength in trained people who exercise in gyms.

Conclusions

The current study evaluated the effectiveness of creatine supplementation in improving athletic performance, physical endurance, muscle strength, muscle hypertrophy, and functional performance in athletes, people with disabilities, and the elderly. The results confirmed that creatine proved to be an effective and safe tool for improving physical performance and rapid recovery. The effect of creatine on muscle hypertrophy, strength, endurance, cognitive function, and recovery after intense physical exertion was analysed. Studies have shown a positive effect in various groups: professional athletes, the elderly, and patients with chronic diseases. Creatine, especially in combination with physical training and in combination with other substances, has been found to increase athletic performance, help maintain muscle mass and functionality, reduce inflammation, and support cognitive functions. Due to minimal side effects and good tolerance by the body, this compound is increasingly prescribed to people with sarcopenia, muscular dystrophy, and neurodegenerative disorders. An important point for good absorption of creatine-based drugs is a clear dosage and compliance with daily consumption standards.

The results obtained prove the universality of the use of creatine to improve physical performance, and the prevention of muscular dystrophy, certain neurophysiological conditions in different segments of the population. A wide range of applications allows restoring the energy potential of both athletes and the sick and elderly. The described results allow developing a clear picture of the effective effect of creatine on various systems and organs and the prospects for its use in various spheres of life. Promising areas of further research are the study of the long-term effects of creatine on the body and the development of optimal dosage protocols for different population groups. Research on its effects on metabolism, hormone balance, and long-term cognitive functionality is important. Experiments on the use of creatine in the treatment of cancer are both under-researched and promising.

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Conflict of Interest

None.

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Вплив креатину на покращення фізичних показників людини: огляд літератури

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Анотація. Креатин є популярною харчовою добавкою, яка демонструє значний вплив на фізичну продуктивність, силу та витривалість, що робить його актуальним для використання у спорті, реабілітації та підвищенні фізичних можливостей у різних вікових групах. Метою роботи було оцінити ефективність застосування креатину для покращення спортивної продуктивності, фізичної витривалості, м'язової сили, гіпертрофії м'язів та функціональних показників спортсменів, осіб з фізичними обмеженнями та літніх людей. Було проведено аналіз результатів численних експериментальних досліджень, зокрема контрольованих випробувань, систематичних оглядів та метааналізів, які оцінювали вплив креатину на фізичні показники людини, використовуючи комбіновані тренувальні протоколи та різні стратегії дозування. Проведені дослідження свідчать про високу ефективність використання креатину спортсменами і людьми інших професій, пов'язаних як з фізичною, так і розумовою роботою. Він сприяє зменшенню м'язових пошкоджень і підвищенню загальної продуктивності спортсменів, зокрема завдяки збільшенню запасів фосфокреатину та стимуляції анаболічних процесів. У спортсменів креатин сприяє зростанню маси м'язів, зниженню втоми та покращенню інтенсивності тренувань, незалежно від статі. Комбінація креатину з іншими речовинами показала додаткові переваги у збільшенні сили та витривалості. Використання креатину в поєднанні з тренуваннями сприяє регіональній гіпертрофії м'язів, збільшує їхню товщину та об'єм, особливо в умовах обмеження кровотоку. У літніх людей добавка зменшує втрату м'язової маси, покращує силу та функціональні можливості навіть за низького рівня фізичної активності. Креатин зменшує відчуття втоми та покращує функціональні показники у пацієнтів із хронічними захворюваннями та нейродегенеративними станами. Результати вказують на універсальність креатину як ефективного засобу для підвищення спортивних результатів, функціональних показників та відновлення після навантажень у різних групах населення. Його застосування рекомендоване для професійних спортсменів, літніх людей та осіб із підвищеними фізичними потребами

Ключові слова: харчові добавки; спортивна продуктивність; фізична працездатність; функціональна ефективність; м'язова сила; гіпертрофія м'язів