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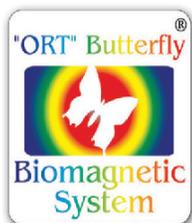
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A review of the effects of nutritional supplements on muscle strength and endurance in athletes

Przegląd wpływu suplementów diety na siłę i wytrzymałość mięśni u sportowców

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Abstract

Athletes widely use nutritional supplements to increase muscle strength and endurance. This review aims to summarize the effects of commonly used dietary supplements on muscle strength and endurance in athletes. A literature search identified several dietary supplements studied for their impact on muscle performance, including protein supplements, creatine, beta-alanine, branched-chain amino acids (BCAAs), caffeine, nitrates, and vitamins and minerals. The review discussed the mechanisms by which this supplement affects muscle strength and endurance. The review methodology includes a systematic literature search, study selection, and data analysis. The review summarizes the effects of each type of supplement on muscle strength and endurance based on the available literature. The discussion includes an overview of the effectiveness and safety of using nutritional supplements to increase muscle strength and endurance in athletes, as well as limitations of studies reviewed and directions for future research. In conclusion, this review highlights the importance of choosing the right and safe nutritional supplements to improve muscle performance in athletes.

Keywords

nutritional, supplements, muscle strength, endurance

Streszczenie

Sportowcy powszechnie stosują suplementy diety w celu zwiększenia siły i wytrzymałości mięśni. Celem tego przeglądu jest podsumowanie wpływu powszechnie stosowanych suplementów diety na siłę i wytrzymałość mięśni u sportowców. W ramach przeglądu literatury zidentyfikowano kilka suplementów diety badanych pod kątem ich wpływu na wydajność mięśni, w tym suplementy białkowe, kreatynę, beta-alaninę, aminokwasy rozgałęzione (BCAA), kofeinę, azotany oraz witaminy i minerały. W przeglądzie omówiono mechanizmy, za pomocą których dany suplement wpływa na siłę i wytrzymałość mięśni. Metodologia obejmuje systematyczny przegląd literatury, wybór badań i analizę danych. Przegląd podsumowuje wpływ każdego rodzaju suplementu na siłę i wytrzymałość mięśni w oparciu o dostępną literaturę. Omówienie obejmuje przegląd skuteczności i bezpieczeństwa stosowania suplementów diety w celu zwiększenia siły i wytrzymałości mięśniowej u sportowców, a także ograniczenia recenzowanych badań i kierunki przyszłych badań. Podsumowując, niniejszy przegląd podkreśla znaczenie wyboru odpowiednich i bezpiecznych suplementów diety w celu poprawy wydajności mięśni u sportowców.

Słowa kluczowe

żywienie, suplementy, siła mięśni, wytrzymałość

Introduction

The use of nutritional supplements has been controversial among athletes, coaches, and health professionals. Dietary supplements can benefit athletes by improving muscle strength and endurance performance. However, improper use of nutritional supplements can adversely affect athletes' health and sports performance. The use of dietary supplements in sports has been a controversial topic due to the potential benefits and risks associated with their use [1].

Using nutritional supplements is common among athletes to improve their physical performance and meet their dietary needs. However, the use of these supplements is a controversial topic due to their potential risks, especially when taken improperly or fraudulently [2].

Sports require high energy consumption, and the nutritional needs of athletes are very different from the dietary needs of ordinary people. They require more specific nutrients to support muscle growth, maintenance, and recovery. To meet these nutritional needs, athletes often consume dietary supplements in addition to their diet [3]. Emphasize that consuming nutritional supplements only needs to be done if it is needed and in the right amount. Taking too many dietary supplements can result in serious health risks for athletes [4]. Athletes' nutritional needs that are different from those of ordinary people are strongly influenced by intense physical activity and require high energy. Athletes require a proper and balanced intake of nutrients to support the growth, maintenance, and recovery of their muscles. Nutritional supplements can be added to nutritional intake, but do not have to be a substitute for food. Consumption of dietary supplements should be based on individual needs and is recommended to be done with the supervision of a nutritionist or sports specialist. Energy requirements for training and competition can be very high. Athletes must consume adequate amounts of carbohydrates, fats, and proteins to boost their performance and support recovery after exercise. Athletes may also require higher doses of certain vitamins and minerals to support their increased metabolic needs and to maintain immune function [5]. However, it is important to remember that nutritional supplements should only be used as a supplement to a proper diet, not as a meal replacement. Taking too many dietary supplements can result in an excess of certain nutrients, which can harm health and trigger unwanted side effects. Excessive use of nutritional supplements can lead to certain nutrients that adversely affect health. Therefore, athletes should note that dietary supplements should only be used as a supplement to a proper diet, not as a substitute [6].

Therefore, conducting a comprehensive literature review is important to understand the effects of nutritional supplements on athletes' muscle strength and endurance. This literature review aims to provide accurate and up-to-date information on the impact of dietary supplements on athletes' muscle strength and endurance and recommendations regarding their use.

The literature review will include the definition and types of nutritional supplements commonly consumed by athletes, as well as a literature review of the effects of dietary supplements on athletes' muscle strength and endurance. The research methodology used in the literature review will also be described in detail. Knowing the impact of nutritional supplements on athletes' mu-

scle strength and endurance is hoped that athletes and coaches can make informed decisions regarding the use of dietary supplements that suit their needs. Health professionals can also provide appropriate recommendations regarding using nutritional supplements in athletes.

In this literature review, we will evaluate the effectiveness and safety of using nutritional supplements on muscle strength and endurance of athletes. We will also discuss the mechanism of action of dietary supplements that affect the strength and endurance of athletes' muscles. That way, this literature review will provide a better understanding of the use of nutritional supplements in sports, so that they can help improve the performance of athletes and maintain their health.

Literature review

Understanding and types of nutritional supplements commonly consumed by athletes

The use of nutritional supplements has become popular among athletes as a way to improve their sports performance. The different types of dietary supplements available on the market and consumed by athletes include protein supplements, creatine, beta-alanine, branched-chain amino acids (BCAAs), caffeine, nitrates, vitamins, and minerals.

Protein supplements are the most common type of nutritional supplement consumed by athletes. Protein is an important nutrient for muscle formation and maintenance, so adequate protein consumption is highly recommended for athletes. Protein supplements are available in various forms, such as powders, bars, and capsules, with whey protein and casein being the most commonly used [7]. As they are easily digested and quickly absorbed by the body. Protein supplements are indeed very important for athletes to help promote muscle growth, with whey protein and casein being common choices consumed by athletes [8].

Creatine is a supplement commonly used by athletes to improve muscle strength and sports performance. Creatine is found in muscles and can increase ATP synthesis, the main energy source for muscle contraction. BCAAs are also a type of supplement commonly consumed by athletes to help speed muscle recovery and increase protein synthesis [9]. Nutritional supplements, including creatine and BCAAs, can help improve muscle growth and exercise performance [10, 11].

Caffeine is a stimulant supplement athletes use to improve focus and sports performance. Caffeine can increase endurance and reduce fatigue, which can help athletes to perform better during training or matches [12]. Caffeine is one of the most widely used supplements among athletes, as it is believed to improve focus, improve performance, and reduce fatigue during exercise. Caffeine has been shown to consistently improve performance on various types of training, including aerobic and anaerobic exercise, caffeine increases exercise endurance by increasing energy production and increasing the body's ability to use fat as an energy source during exercise [13].

Nitrates are a type of supplement that can increase aerobic capacity by increasing oxygen delivery to muscles. Nitrates can be found in foods such as beets, spinach leaves, and rucola, and are available in supplement form. Nitrates can improve athletes' performance and be an effective and safe alternative to increasing aerobic capacity during physical exercise [14].

Vitamins and minerals are also very important for athlete health and sports performance. Nutritional deficiencies can interfere with sports performance and cause fatigue. Vitamin and mineral supplements help ensure that athletes get adequate nutrition and maintain their health [15, 16]. Athletes taking vitamin D supplements in the right dose experience improved physical performance and faster recovery after intense training. Vitamin and mineral supplements help ensure that athletes get adequate nutrition and maintain their health. Therefore, athletes must watch their nutritional intake and add vitamin and mineral supplements [17].

Overall, taking nutritional supplements can benefit athletes, but can also carry risks if not used properly. Therefore, before taking dietary supplements, athletes should consult a doctor or nutritionist to ensure their use is safe and effective.

A literature review of the effects of nutritional supplements on athletes' muscle strength and endurance includes

Protein supplements

Protein is one of the essential macronutrients needed by the body to build and repair muscle tissue. Protein can be found in various food sources, including meat, eggs, milk, nuts, and seeds [18]. Protein plays an important role in building and repairing muscle tissue.

Protein plays an important role in building and repairing muscle tissue in the body. In addition, protein also plays a role in the body's metabolic processes, such as the formation of enzymes, hormones, and neurotransmitters [19]. Protein has an important role in repairing muscle damage during exercise and facilitating muscle recovery after exercise. In addition, protein is also needed to produce enzymes, hormones, and neurotransmitters that play a role in various metabolic processes of the body.

Athletes often take protein supplements to help improve their muscle strength and endurance. Some types of protein commonly consumed by athletes include: (1). Whey protein: protein taken from milk, which is easily digested and absorbed by the body; (2). Casein protein is also taken from milk but digested more slowly than whey protein; (3). Plant protein: protein derived from vegetable sources, such as soybeans, nuts, and seeds [20]. The most common proteins athletes consume, such as whey protein, casein protein, and vegetable protein, have all been shown to be effective in increasing muscle mass and muscle strength.

The mechanism of action of a protein in increasing muscle strength and endurance Protein helps improve muscle strength and endurance by stimulating muscle protein synthesis, which is the process of forming new proteins in muscle tissue. In addition, protein also helps repair damage to muscle tissue after strenuous exercise [21]. Increasing circulating amino acids (AAs) is a powerful stimulus for increased MPS (muscle protein synthesis). This increase in MPS is an underlying mechanism of muscle hypertrophy (i.e., muscle growth) in response to resistance exercise.

Scientific evidence on the effectiveness of protein in increasing muscle strength and endurance. Research conducted obtained results that regular consumption of whey protein supplements can increase muscle strength and endurance in women who practice [22, 23]. A study by [24] found that regular consumption

of whey protein supplements can increase muscle strength and hypertrophy in older adults. However, research results vary depending on the subject, dosage, type of protein, and research method used.

Although protein supplements are considered safe in recommended doses, excessive consumption can increase the risk of health problems, such as kidney damage, kidney stones, and indigestion [25]. Consumption of protein supplements in high doses can increase the risk of kidney damage and kidney stones in individuals with impaired kidney function.

The recommended dosage and mode of use of protein supplements may vary depending on the type of protein used and the purpose for which it is used. However, consuming 20–30-gram protein after exercise is generally recommended to help repair muscle tissue and speed recovery. In addition, it is also important to pay attention to protein intake from daily food so as not to exceed the body's needs. The recommended dosage for the use of protein supplements varies depending on the type of protein, the purpose of use, and the individual condition, in general, consumption of 0.25–0.3-grams of protein per kilogram of body weight every 3–4 hours can help maximize muscle protein synthesis, in addition, it is important to pay attention to protein intake from the daily diet to avoid excess protein that can harm kidney and heart health [26].

Creatine supplements

Creatine is an organic compound found in muscles and food Creatine is an organic compound consisting of the amino acids arginine, glycine, and methionine. This compound is present in skeletal muscle and can also be found in foods such as meat and fish. Creatine is important in cellular energy metabolism, especially in high-intensity and short-duration physical activity.

Creatine works by increasing the amount of creatine phosphate available in the muscles, thereby increasing the production of ATP (adenosine triphosphate) during intense exercise. ATP is the main source of energy for cells in the human body, and creatine phosphate helps regenerate ATP that is broken down during physical activity. By increasing ATP production, creatine supplements can help improve the performance of sports that require muscle strength and endurance, such as lifting weights or sprints. Creatine supplements may also help reduce muscle fatigue during intense exercise.

Results of a literature review related to the effects of creatine supplements on athletes' muscle strength and endurance Various literature reviews have been conducted to evaluate the effects of creatine supplements on athletes' muscle strength and endurance. Some of the results of the literature review are:

(1). Increased muscle mass and strength: Creatine supplements effectively increase muscle mass and strength, especially in weight-training athletes. Research conducted [27] the results showed that creatine supplements can increase muscle strength and muscle power in various groups of athletes, including soccer players, weightlifters, and sprinters. In addition, the authors also found that creatine supplements can improve muscle recovery after exercise and may contribute to increased muscle mass in older people. Research conducted [28], the results showed that creatine supplements could increase strength and muscle mass in trained men.

(2). Increased muscular endurance and anaerobic ability: Creatine supplements can also improve muscle endurance and anaerobic ability, such as in sprints and weight lifting. Research conducted [29] the results showed that creatine supplementation for 28 days, combined with resistance training, significantly improved body composition, maximum strength, and power output, as well as increased anaerobic endurance capacity. In addition, research conducted [30] shows the results of creatine supplements have been shown to improve the performance of high-intensity exercise, especially through increasing energy availability for anaerobic metabolism

(3). Reduction of muscle fatigue during intense exercise: Some studies show that creatine supplements can help reduce muscle fatigue during intense exercise, thereby improving athlete performance. Research conducted [31] shows supplementation with creatine has been shown to increase muscle creatine content, improving muscle performance, especially during high-intensity exercise of short duration. Research conducted [32] showed results that creatine, in addition to increasing strength and endurance, creatine supplements have been associated with reduced fatigue and increased work performed during high-intensity exercise.

Creatine is very good in increasing muscle strength and endurance but in its use, the dosage must be considered, the recommended creatine supplement dosage varies depending on the type of supplement and individual needs. However, the standard dose for creatine monohydrate supplements is 3–5 grams daily for 4–6 weeks in the early stages of use, followed by a maintenance dose of about 2–3 grams daily.

The use of creatine, if not used with the correct dose, will cause side effects that may occur due to the use of creatine supplements, are dehydration and digestive disorders, such as diarrhea, nausea, and stomach cramps. However, these side effects usually occur with high doses and long-term use, so using creatine supplements with the right amount and controlled duration is safe. Before taking creatine supplements, you should consult a doctor or nutritionist, especially if you have a history of kidney disease or other health problems.

Beta-alanine supplements

Beta-alanine supplements and their mechanism of action in increasing muscle strength and endurance Beta-alanine supplements contain the amino acid beta-alanine, which acts as a precursor for the synthesis of karosine in the body. Karosine itself is a compound in the body that balances muscle pH and prevents lactic acid evaporation during physical activity. Thus, beta-alanine supplements are expected to increase muscle capacity for intense physical action and muscle endurance.

Studies that show the effectiveness of beta-alanine supplements in improving athlete performance Studies that have been conducted show that the use of beta-alanine supplements can enhance the performance of athletes in various types of sports. Studies led [33] show that beta-alanine supplementation has a positive effect on anaerobic performance variables in female athletes and can improve the ability to perform high-intensity exercise, such as sprinting [34]. Research results suggest that beta-alanine supplementation can improve physical performance in healthy individuals, including anaerobic power, capacity, and

exercise volume, which can result in improvements in high-intensity exercise tasks, such as sprinting and jumping.

Studies reveal that using beta-alanine supplements can improve anaerobic capacity and motor skills in football and basketball. Research conducted by [35, 36] that using beta-alanine supplements can increase anaerobic capacity in soccer players. The results showed that beta-alanine supplements could increase the body's capacity to produce anaerobic energy and improve players' ability to perform intense anaerobic tasks. Using beta-alanine supplements can also improve performance during HIIT (High-Intensity Interval Training) training on stationary bikes. The meta-analysis results support the hypothesis that beta-alanine supplementation is a beneficial ergogenic aid for exercise capacity and performance during high-intensity exercise protocols such as HIIT [37]. Beta-alanine supplements can also increase endurance time on running workouts and time to fatigue on cycling workouts [38]. Research shows that beta-alanine supplements can increase aerobic and anaerobic capacity in athletes, extending endurance time on running and cycling exercises.

Dosages are commonly used in studies and dosage recommendations that are safe for use in athletes. The usual dose used in studies was about 4–6 grams per day, with administration for 4–12 weeks. However, safe dosage recommendations for athletes will depend on factors such as weight, type of exercise, and purpose of use. Some sources recommend a dosage of about 2–5 grams per day for long-term use.

A side effect associated with the use of beta-alanine supplements is a burning sensation in the skin known as paresthesia. These side effects usually occur at high doses and are harmless. Factors such as dosage and duration of use can affect the severity of side effects experienced. In addition to side effects, there are potential interactions between beta-alanine supplements and drugs that affect the central nervous and cardiovascular systems. However, data regarding drug interactions with beta-alanine supplements are still limited and require further research.

Branched-chain amino acid supplements (BCAAs)

Understanding and characteristics of BCAA, BCAA stands for "branched-chain amino acid" or branched-chain amino acid, which consists of three amino acids: leucine, isoleucine, and valine. BCAAs are essential amino acids, which means the body cannot produce its own and must be obtained through food or supplements [39]. BCAAs, including leucine, isoleucine, and valine, are essential amino acids that cannot be synthesized by the human body and must be obtained through food or supplements". This BCAA amino acid is very important in muscle metabolism and plays a role in increasing muscle protein synthesis, suppressing muscle damage, and promoting muscle growth and recovery [40]. BCAA drinks can help reduce muscle breakdown and improve muscle recovery during high-intensity exercise.

BCAAs can be obtained through meat, eggs, soy, and dairy products [41]. BCAA's main food sources include animal proteins, such as meat, eggs, and dairy products, and plant proteins, such as soy. However, to get high enough doses to improve sports performance, many athletes and sports coaches take BCAA supplements. The types of BCAA supplements available on the market include powders, tablets, capsules, or sports drinks. Some BCAA supplement manufacturers combine BCAAs with other ingredients such as glutamine, electrolytes, or caffeine.

BCAAs work in the body in several ways, including increasing muscle protein synthesis by increasing the availability of amino acids in the body, reducing muscle damage during physical exercise, and increasing muscle growth [42]. BCAAs can increase muscle protein synthesis and affect amino acid metabolism in the body, thereby increasing the availability of amino acids in the body. BCAAs can also help increase insulin production, which can help increase the uptake of glucose and amino acids by muscles during physical exercise [43]. BCAA supplementation may be a nutritional strategy to improve insulin resistance, which may contribute to increased glucose uptake by muscles during exercise.

Based on the results of a literature review, the use of BCAA supplements can help increase muscle strength and endurance in athletes. BCAAs increase muscle protein synthesis, thereby helping to increase muscle mass and muscle strength. BCAAs can also reduce muscle breakdown during exercise, thus helping to improve muscle recovery and muscular endurance during exercise. Research conducted by [44] shows that BCAAs can reduce muscle damage during exercise in men who have become accustomed to training with weights. Research [45] shows that leucine supplementation (as one of the components of BCAAs) during resistance training exercise can help reduce muscle damage, increase muscle strength and hypertrophy. However, the results of existing studies are still mixed and not yet fully consistent regarding the effects of BCAAs on muscle strength and endurance of athletes.

Although the use of BCAA supplements is generally considered safe, long-term use or excessive doses can cause some side effects. Some of the possible side effects include indigestion, headaches, sleep disturbances, and an increased risk of liver or kidney disease [46]. Meta-analysis results showed that BCAA supplementation had a negative effect on estimated glomerular filtration rate (eGFR) and blood urea nitrogen (BUN) in all subjects. Therefore, the use of BCAA supplements should be done by following the recommended dosage and with strong medical supervision. In addition, keep in mind that BCAA supplements cannot replace a balanced diet and adequate protein intake from the daily diet.

BCAA supplements can be an option for increasing muscle strength and endurance in athletes, but keep in mind that research results are still mixed and side effects from using BCAA supplements also need to be noted. We recommend that the use of BCAA supplements be done with medical supervision and follow the recommended dosage, and do not replace a balanced diet and adequate protein intake from the daily diet.

Caffeine supplements

Caffeine is a stimulant compound that affects the central nervous system and can trigger adrenal hormones such as adrenaline and noradrenaline. This hormone can increase muscle contractions and increase endurance. Some research also suggests that caffeine can affect muscle metabolism and increase the ability of muscles to produce energy. Caffeine increases the oxidative capacity and breakdown of glycogen in muscle training, which contributes to the increase in aerobic capacity and endurance performance observed after caffeine consumption in the studies conducted [47, 48]. Caffeine digestion increases isokinetic mu-

scle strength by increasing muscle activation and reducing muscle fatigue during exercise.

The effective and safe dose of caffeine for athletes varies depending on factors such as body weight, individual tolerance, and the type of exercise performed. Most research suggests that doses of 3–6 mg/kg of body weight about an hour before exercise can improve athlete performance [49]. Giving caffeine about an hour before exercise, caffeine doses of about 3–6 mg/kg of body weight were found to improve athletes' performance in prolonged training and strength [50]. In studies with doses of approximately 3–6 mg/kg of body weight given about an hour before exercise, athletes' performance on prolonged exercise and strength improved significantly.

However, there are also studies that show lower or higher doses can have the same effect [51]. There was no significant difference in maximal strength and power output between the caffeine and placebo groups at either dose (3 or 6 mg/kg), which suggests that the ergogenic effects of caffeine may not be dose-dependent. In addition, it is important to pay attention to the timing and pattern of caffeine consumption, such as avoiding caffeine consumption before bed or reducing consumption if a person has heart problems or caffeine addiction.

Research shows that caffeine can increase the ability of muscles to work in hypoxic conditions and increase aerobic capacity, which can increase muscle endurance in exercise [52]. research conducted shows that caffeine consumption has a significant effect on muscle endurance performance, with a moderate effect size ($g = 0.52$), which is equivalent to an average muscle endurance performance increase of 5.5%.

Effects of caffeine on muscular endurance: Some research suggests that caffeine can improve the ability of muscles to work in hypoxic conditions and increase aerobic capacity, which can increase muscular endurance at exercise. [53–55] an analysis of various studies on the effect of caffeine on athletes who exercise in hypoxic conditions and found that caffeine supplements can improve the performance of athletes in these conditions. Research shows that caffeine can increase the time to fatigue or increase the distance that can be traveled, especially in extended exercise [56]. Found that caffeine supplementation can increase the time it takes to achieve fatigue in maximal ergometer training in male rowing elite athletes.

Safety of caffeine use: Although caffeine has potential benefits for improving athletes' performance, it also has certain side effects and risks especially if used in excessively high doses or combined with other compounds. Possible side effects include headaches, anxiety, tremors, sleep disturbances, and digestive problems. In addition, the use of caffeine can also trigger an increase in heart rate, increase the risk of dehydration, and affect the absorption of nutrients in the body. Therefore, before using caffeine supplements, athletes should consult with a doctor or nutritionist to find out the dosage that is safe and suitable for their individual needs.

Nitrate supplements

Nitrate supplements are usually in the form of sodium nitrate or nitrate contained in vegetables such as beets (beetroot juice). Sodium nitrate is commonly used in supplements available in the market. While beets are rich in nitrates, often processed into juice

or supplements that are easier for athletes to consume [57]. The authors discuss that sodium nitrate is a commonly used source of nitrate as a supplement in sports, due to its ability to increase oxygen delivery to muscles and improve athletic performance.

How nitrates can improve athletes' performance through the formation of nitric oxide (NO) in the body: Nitrates are converted into nitric oxide (NO) in the body. NO is a chemical compound that plays an important role in the regulation of blood flow and cellular functions in the body. Nitrate supplements are expected to increase NO levels in the body and increase blood and oxygen flow to the muscles [58]. Nitrate supplements improve exercise performance by increasing nitric oxide (NO) bioavailability, thereby improving blood flow, muscle contractile efficiency, and mitochondrial respiration.

Effects of nitrate supplements on athletes' performance in various types of sports, such as long-distance running, cycling, and weightlifting. Several studies have shown that the consumption of nitrate supplements can improve the performance of athletes in certain types of sports. [59] studies conducted on long-distance running athletes show that consumption of nitrate supplements can increase travel time and reduce fatigue [60]. performance improvement was also seen in cyclists and weightlifters after taking nitrate supplements.

The mechanism of action of nitrates in increasing muscle oxygenation and reducing fatigue during sports activities. Nitrate supplements can increase blood flow to muscles and increase oxygen levels available in muscles during sports activities. This can slow fatigue and allow athletes to exercise at a higher intensity or for longer periods [61]. Nitrate supplementation has the potential to increase the bioavailability of NO and thus increase skeletal muscle blood flow and reduce the cost of exercise O_2 . Collectively, these effects can translate into improved exercise performance and extended duration of high-intensity exercise

Potential side effects and health risks associated with taking nitrate supplements, such as hypotension (low blood pressure) and cancer risk. Excessive consumption of nitrate supplements can cause hypotension (low blood pressure) in some people. In addition, there are several studies that associate high amounts of nitrate consumption with an increased risk of cancer, research conducted [62] revealed that high consumption of nitrates and nitrites can increase the risk of type 2 diabetes mellitus (T2DM). This can be attributed to the potential formation of nitrosamines, which are known to have adverse effects on glucose metabolism and insulin sensitivity. However, more research is still needed to confirm this.

Dosage recommendations and the duration of consumption of safe and effective nitrate supplements vary depending on the type of supplement and the individual needs of the athlete. However, the generally used dosage is about 6–8 mmol or 300–400 mg of nitrate supplements per day for a few days before competition or intense exercise. The optimal dose and duration of nitrate supplementation remains unclear, although studies have shown that 6–12 mmol of dietary nitrate per day for 3–7 days is effective in improving endurance exercise performance in healthy adults [63]. However, it is important to consult a doctor or nutritionist before taking nitrate supplements, especially if you have a medical history or are taking certain medications.

Nitrate supplements can improve athletes' performance and reduce fatigue during sports activities. However, consumption of

nitrate supplements can also cause hypotension and there are potential health risks associated with excessive consumption. Therefore, it is important to consult a nutritionist or doctor before taking nitrate supplements and follow the recommended dosage.

Vitamin and mineral supplements

Vitamins and minerals are essential for the body to carry out important biological functions including to increase muscle strength and endurance. Some types of vitamins and minerals that are often consumed by athletes include vitamin C, vitamin D, vitamin E, magnesium, calcium, iron, and zinc. Vitamins C and E have a role as antioxidants that can protect muscles from cell damage, while vitamin D helps the absorption of calcium which is important for bone health and muscle contraction. Magnesium, calcium, and zinc also have important roles in muscle contraction and energy metabolism [64].

Effects of vitamin and mineral deficiencies on athletes' muscle strength and endurance. Vitamin and mineral deficiencies can have an impact on decreasing the strength and endurance of athletes' muscles. For example, iron deficiency can lead to anemia, which can result in fatigue, decreased endurance and athlete performance [65]. Magnesium deficiency has also been linked to decreased athlete performance and exercise ability, as well as muscle fatigue [66].

The mechanism of action of vitamins and minerals in the body and how they can affect muscle strength and endurance. Vitamins and minerals play a role in various metabolic and biological processes related to muscle strength and endurance. For example, magnesium helps in the process of energy formation in cells, and plays an important role in muscle contraction [67]. Calcium is also important in muscle contraction, while vitamin D is needed in calcium absorption in the body [68]. Vitamins C and E act as antioxidants, which can protect muscles from cell damage caused by intense exercise activities [69].

Evidence from studies examining the effectiveness of vitamin and mineral supplements in increasing muscle strength and endurance in athletes. Some studies show that taking vitamin and mineral supplements can improve muscle strength and endurance in athletes. For example, a study found that magnesium consumption can improve athletes' performance in swimming and running activities [66]. In addition, a literature review found that vitamin D supplementation can improve muscle strength and exercise performance on [68]. However, not all studies show consistent results. A study conducted on running athletes found that consumption of vitamin C and E supplements did not have a significant effect on athlete performance [69]. Therefore, before taking vitamin and mineral supplements, it is important to consult a nutritionist or doctor to determine the right dosage and ensure their safety and effectiveness.

The mechanism of action of nutritional supplements that affect the strength and endurance of athletes' muscles

Protein supplements generally serve as a source of amino acids needed by the body for muscle protein synthesis. Protein supplements consumed before and after exercise can increase muscle protein synthesis, reduce muscle damage, and accelerate muscle recovery after exercise [70]. A 2019 study found that protein consumption immediately after exercise can increase muscle strength and muscle endurance [71].

Creatine is a compound present in the body and serves as a source of energy for muscles during physical activity. Creatine supplements can increase the availability of ATP in muscles and help increase muscle strength and endurance during strenuous and short physical activity. A study in 2020 found that taking creatine supplements for 4 weeks can increase muscle strength and endurance in athletes [72].

Beta-alanine supplements: Beta-alanine is an amino acid that serves as a precursor to carbamic acids, which increases the concentration of acid buffer in muscles. Beta-alanine supplements can increase the acid buffer capacity of muscles and delay muscle fatigue during strenuous and repetitive physical activity. A study in 2018 found that taking beta-alanine supplements for 4 weeks can improve muscle endurance in athletes [73].

Branched chain amino acid (BCAA) supplements: BCAAs consist of three essential amino acids namely leucine, isoleucine, and valine. BCAA supplements can increase muscle protein synthesis, reduce muscle breakdown, and delay muscle fatigue during physical activity. A 2019 study found that taking BCAA supplements before and during exercise can improve muscle strength and muscle endurance [74].

Caffeine supplements: Caffeine is a stimulant compound that can improve concentration and focus, as well as increase muscle strength and endurance during physical activity. Caffeine works by increasing the concentration of adenosine in the brain, which helps increase endurance and delay muscle fatigue. A 2021 study found that caffeine consumption before exercise can improve muscle strength and muscle endurance in athletes [75].

Methodology

In this study, the databases used, namely PubMed and Scopus, in searching literature the keywords used include:

1. Nutritional supplements AND athletes AND muscle strength
2. Nutritional supplements AND athletes AND endurance
3. Protein supplements AND athletes AND muscle strength
4. Creatine supplements AND athletes AND muscle strength
5. Beta-alanine supplements AND athletes AND endurance
6. Branched-chain amino acid (BCAA) supplements AND athletes AND muscle strength
7. Caffeine supplements AND athletes AND endurance
8. Nitrate supplements AND athletes AND endurance

Table 1. The inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Studies examining the effects of nutritional supplements on muscle strength or endurance in athletes, with participants aged 18 years and older competing or training regularly	Studies that do not meet the inclusion criteria, studies conducted on animals, studies conducted in clinical populations, studies published before 2015, and studies that are not available in English

Studies examining the effects of nutritional supplements on muscle strength or endurance in athletes, with participants aged 18 years and older competing or training regularly. Studies that do not meet the inclusion criteria, studies conducted on animals, studies conducted in clinical populations, studies published before 2015, and studies that are not available in English.

The number of studies identified through the search strategy, and the selection process of studies conducted, Studies identified through PubMed and Scopus database searches are taken and incorporated into reference management software, such as Mendeley or Zotero. From the studies identified, the initial step is to evaluate the title and abstract to determine whether the

study meets the inclusion criteria. Studies that pass the first phase will be considered for further analysis, including checking full-text studies and evaluating the quality of studies identified using predetermined quality criteria.

Result

From the discussion in the literature review points, it has been fully explained about the effects of supplements, the mechanism of action of supplements, evidence of studies that examine supplements in increasing muscle strength and endurance of athletes, but to make it easier to see results, the table below is the result of an explanation of the effects of nutritional supplements on muscle strength and endurance in athletes

Table 2. Literature review

Author and year	Article Title	Journal title	Result
Jones, L. C. et al. 2018 [76]	The effects of protein supplementation on muscle strength, hypertrophy, and recovery in resistance-trained individuals	Journal of the International Society of Sports Nutrition	Protein supplements can increase muscle protein synthesis and muscle strength in athletes with adequate consumption
J. Grgic et al. 2021 [77]	Test-Retest Reliability of Caffeine Effects on Maximal Strength and Power in Trained Men	Journal of Strength and Conditioning Research	Creatine supplements are effective in increasing muscle strength and muscular endurance in athletes, especially in anaerobic exercise

Author and year	Article Title	Journal title	Result
B. Saunders et al. 2017 [78]	Beta-alanine supplementation to improve exercise capacity and Performance: A Systematic Review and Meta-Analysis	British Journal of Sports Medicine	Beta-alanine supplements can increase muscle working capacity and muscular endurance in athletes
C. M. Kerksick, C. D. Wilborn, and B. I. Campbell, 2018 [15]	International Society of Sports Nutrition position stand: dietary supplements for exercise and athletic performance	Journal of the International Society of Sports Nutrition.	Taking BCAAs before or during exercise can help repair muscle damage and increase muscular endurance in athletes.
K. Southward, K. J. Rutherford-Markwick, and A. Ali. 2018 [79]	The effect of acute caffeine ingestion on endurance performance: a systematic review and meta-analysis	Sports Medicine	Caffeine consumption can increase muscle strength and endurance in athletes, especially in aerobic exercise,
Jones, A. M. et al. 2018 [80]	Dietary nitrate supplementation and exercise performance: questions and challenges	Sports Medicine	Consumption of nitrate supplements can increase oxygen use by muscles and muscular endurance in athletes

Discussion

The effectiveness and safety of the use of nutritional supplements on muscle strength and endurance of athletes. A review of the literature suggests that the use of certain types of nutritional supplements can improve muscle strength and endurance in athletes. For example, research by [81] found that beta-alanine supplements can increase muscle strength and endurance in weight lifters. However, it is important to pay attention to the proper dosage and use to avoid dangerous side effects. A study by [82] showed that high doses of vitamin D can cause poisoning, so safe and appropriate doses must be observed.

Although the literature review showed positive results, there were still limitations in the methodology and design of the studies conducted. A study by [83] showed that some studies were limited by a small sample and not diverse enough in terms of the type of sport or athlete studied. Therefore, better designed and broader studies in terms of population and type of exercise studied need to be done to clarify the effects of nutritional supplements on muscle strength and endurance.

Implications of results on athletes' training and nutrition strategies: Findings from this literature review may assist trainers and athletes in choosing the right type of nutritional supplement to increase muscle strength and endurance. Research by [84] shows that adequate protein intake can help increase muscle protein synthesis in athletes who have muscle damage. However, it is important to remember that proper nutrition also plays an important role in increasing muscle strength and endurance [85–87]. A study by [88] showed that inadequate nutrient intake can affect athletes' ability to develop muscle strength and endurance.

Controversies and debates related to the use of nutritional supplements. The use of nutritional supplements in athletes is still a controversial debate. Some studies show that the use of

nutritional supplements can improve the performance of athletes, while others show that there is no significant benefit. A study by [89] shows that most nutritional supplements have little scientific evidence to support their claims, so it is important to be careful and pay attention to the source and type of supplement used.

Although there are still controversies and limitations in this literature review, in general, the use of nutritional supplements can provide benefits for muscle strength and endurance in athletes. However, it is important to pay attention to proper dosage and use and consider proper nutrition.

In terms of future research directions, further research with better and broader designs and methodologies is needed to clarify the effects of nutritional supplements on muscle strength and endurance in different types of sports and athlete populations.

Conclusion

Based on the results of this literature review, it can be concluded that nutritional supplements can increase the strength and endurance of athletes' muscles. Some types of nutritional supplements that have been shown to be effective in improving athlete performance are protein supplements, creatine supplements, beta-alanine supplements, branched chain amino acid (BCAA) supplements, caffeine supplements, and nitrate supplements. However, it is important to remember that improper and safe use of nutritional supplements can have a negative impact on athletes' health. Therefore, it is advisable to consult a nutritionist or sports doctor before using nutritional supplements and choose nutritional supplements that are proven to be effective and safe.

A limitation of this literature review is that most studies were conducted on male athletes with varying durations of supplement use, making it difficult to make broader generalizations. In addition, more research is needed to clarify the effectiveness and safety of nutritional supplements in different populations of

athletes and to evaluate the long-term effects of nutritional supplement use on athlete health.

In practice, it is important to pay attention to the consumption of adequate and balanced nutrition, as well as regular and measurable exercises in increasing the strength and endurance of the athlete's muscles. The use of nutritional supplements should be considered carefully and should only be a nutritional additive, not a substitute for nutrients derived from food. By choosing the right and safe nutritional supplements, and paying

attention to regular and measurable nutrition and exercise, athletes can significantly improve their performance.

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