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Jurnal Keolahragaan, 11 (1), 2023, 10-23

Literature review: nutrition supplementation for muscle fatigue in athletes

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Received: 27 December 2021; Revised: 26 January 2023; Accepted: 13 April 2023

Abstract: The use of natural or conventional-based supplementation has become a popular strategy among athletes seeking to reduce oxidative stress, improve recovery, and enhance athletic performance. This literature review searched four reputable international electronic databases, including PubMed, MedRxiv, Cochrane, and Clinical Trial.gov until December 2021, using Boolean operators with keywords and Mesh methods. The keywords used were "Supplementation", AND "Muscle Fatigue Recovery", AND "Athletes", which yielded 24 articles as study findings. The literature review found that exhaustive exercise can induce a neutrophil antioxidant response by increasing antioxidant enzymes. Nutritional supplements, specifically antioxidant supplements, Branched Chain Amino Acid (BCAA), citrulline, omega 3, and caffeine, have been scientifically proven to reduce oxidative damage, which can block signaling pathways related to muscle hypertrophy. To combat muscle fatigue in athletes based on this research (literature review), natural ingredients and synthetic nutritional supplements have been utilized as dietary interventions. This literature review identified numerous natural micronutrients and synthetic supplements used in sports that possess anti-fatigue properties, decrease oxidative stress, and enhance athletes' endurance capacity. The effectiveness of nutritional supplements in addressing muscle fatigue may vary based on the various ingredients in the supplements. However, natural-based supplements have become a preferred option among athletes and coaches currently.

Keywords: supplementation, natural ingredients, muscle soreness, athletes

How to Cite: Mardiana, M., Kartini, A., Sutiningsih, D., Suroto, S., & Muhtar, M.S. (2023). Litearure review: nutrition supplementation for muscle fatigue in athletes. *Jurnal Keolahragaan, 11*(1), 1-3. doi:https://doi.org/ 10.21831/jk.v11i1.46486

INTRODUCTION

Muscle fatigue can be attributed to several factors, including the depletion of Adenosine Triphosphate (ATP) (Enoka & Duchateau, 2016), increased degeneration of reactive oxygen species (ROS), resulting in oxidative stress and muscle damage (Steinbacher & Eckl, 2015). Generally, the deleterious influence of fatigue on sports performance is well-established as heavy training can cause cumulative fatigue and reduce the capacity to produce strength. For example, some athletes, such as cyclists, may require up to three days to recover from such conditions fully. In addition to the short-term effects of fatigue on athletic performance, presistent training sessions in a fatigued state can result in suboptimal performance levels during training and competition. Prolonged exposure to cumulative fatigue conditions can the potential to increase the risk of injury (Shing et al., 2016) and a result, undesirable psychological adjusments occur. However, athletes may encounter situations where they must maintain their performance levels under fatigue, such as in marathon and long-distance cycling events (Rodríguez-Marroyo et al., 2017).

The recovery process after a workout is crucial in physical conditioning, particularly in sports performance. It impacts the risk of injury, sports performance, and other factors (Malm et al., 2019; Yuniana et al., 2023). Various techniques, have been shown to improve the recovery process, including manual therapy (MT) (Fuller et al., 2015), mechanical vibration (MV) (Lu et al., 2019) and the foam roller (FR) (FR)(Romero-Moraleda et al., 2019). These techniques can reduce delayed onset muscle

soreness (DOMS), maintain athletic performance, and alleviate pain (Kellmann et al., 2018). Muscle function recovery time may be influenced by various factors, including as age, training history, playing position, level of competition, opponent standard, and number of recovery days from previous training or games (Paul et al., 2015).

Efforts have been made to alleviate complaints resulting from eccentric exercises such as non-steroidal drugs, massage, and muscle therapy with cold water (Abaïdia et al., 2017; Paul et al., 2015; SUGITA et al., 2003; Yuniana et al., 2022). However, the use of drugs may lead to side effects such as digestive disorders such as gastritis and bleeding. According to a study conducted in the United States, 59.8% of high school soccer players reportedly use protein supplements, while only 29.4% use pre-workout supplements (Shoshan & Post, 2021). At Ragunan soccer school, a study revealed that 94% of athletes used supplements in the past year, with 89% using them daily for post-workout or post-game muscle recovery.

Supplementation with natural products has become a popular strategy among athletes at different levels of competition. During continuous training sessions, fatigue can cause oxidative stress and muscle damage. To counter these effects, athletes are turning to natural antioxidants such as green tea extract from Camellia (Machado et al., 2018) which has been shown to be effective. Additionally, soy-based supplements derived from Glycine max L. Additionally, soy-based supplements derived from Glycine max L. Merr can provide nutraceuticals that help prevent chronic diseases in humans. Preliminary studies showed that soy extract has anti-obesity, antiatherogenic, antidiabetic, and anti-inflammatory effects (Tanaka et al., 2014). In a study conducted in Singapore, a group of 10 runners was given soymilk intervention to alleviate muscle fatigue after the Running Anaerobic Sprint Test (RAST), significantly reducing fatigue index. This indicates that soy-based supplements may enhance the performance of athletes involved in anaerobic activities robic (Govindasamy Balasekaran, 2021).

Preliminary studies showed that supplements based on Moringa leaves extract can aid in muscle recovery and have antioxidant, anticancer, anti-inflammatory, and neuroprotective properties, particularly due to high flavonoid and isoquercetin content. Furthermore, studies suggested that *M. oleifera* are traditionally found as promising drugs for various disorders, with neurotropic and neuroprotective effects promoting neurons' growth and survival (Abdull Razis et al., 2014; Kooltheat et al., 2014;Hannan et al., 2014). This literature review aims to conduct a systematic analysis and answer research questions regarding "the effectiveness of supplementation in reducing muscle fatigue in athletes". This study is expected to offer preliminary findings for future study on using supplements to alleviate muscle fatigue among Indonesian athletes. By ensuring the provision of standardized and high-quality nutritional supplements, this approach may enhance the recovery process for athletes and the public in the future.

METHOD

To initiate the literature review, articles were searched across four reputable international electronic databases, namely PubMed, MedRxiv, Cochrane, and ClinicalTrial.gov. The search strategy involved the use of Boolean operators and Mesh methods, using the keywords "Supplementation", "Muscle Fatigue Recovery", AND "Athletes". The complete search methodology is available in the table provided:

Table 1. Article Search Database

No	Database	Number of articles	Include	url
1	PubMed	116	18	https://pubmed.ncbi.nlm.nih.gov/?term=Supplementation+AND+Muscle+Fatigue+Recovery+AND+Athletes&show_snippets=off&size=200
2	MedRxiv	28	2	https://www.medrxiv.org/search/Supplementation%252BAND%252BMuscle%252BFatigue%252BRecovery%252BAND%252BAthletes
3	Cochrane	50	3	https://www.cochranelibrary.com/search
4	Clinical Trial.Gov	1	1	https://clinicaltrials.gov/ct2/results?cond=Supplementation+AND+Muscle+Fatigue+Recovery+AND+Athletes&term

The final number of articles included in the literature review	24

The search across the four reputable article search engines yielded 195 articles until December 12th, 2021. These articles were then screened using inclusion criteria, which included review studies, consensus statements, and original study, particularly clinical articles utilizing the Randomized Controlled Trial (RCT) method was used to examine the effectiveness of supplementation in alleviating muscle fatigue in athletes. The articles had to be published between 2009 and 2021, written in English, fully accessible for free (free full text), and without repetition. Meanwhile, research that did not match the earlier-mentioned inclusion criteria were excluded. A snowballing search was conducted on the reference lists of articles that met the inclusion and exclusion criteria, leading to the identification of additional studies. The final chart detailing the acquisition of articles is presented in Figure 1.

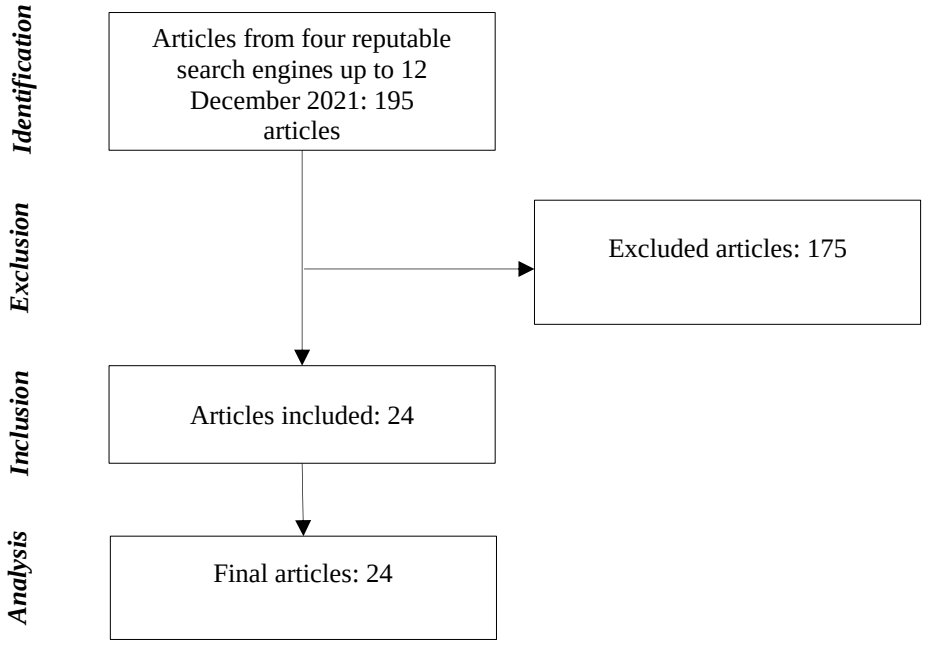

Figure 1. The Final Chart Detailing the Acquisition of Articles

RESULT AND DISCUSSION

Table 2. Search Results for Articles Included in the Literature Review

Title (author, year)	Variable	Study subject	Method	Results
Effect of whey vs. soy protein supplementation on recovery kinetics following speed endurance training in competitive male soccer players: a randomized controlled trial (Kritikos et al., 2021)	Dependent Variable: Acceleration of recovery from exercise-induced muscle damage and markers of redox status. Independent Variable: Administration	10 football athletes	Randomized Controlled Trial	increasing daily protein intake to 1.5 g/kg viz whey or soy protein supplements prevented field performance during consecutive speed endurance training sessions without infuencing exercise-induced muscle damage and indicators of redox status.

Title (author, year)	Variable	Study subject	Method	Results
	of whey or soy protein supplements			
Effects of soymilk ingestion on anaerobic performance and physiological measures (Govindasamy Balasekaran, 2021)	Dependent Variable: Post-exercise muscle recovery running anaerobic sprint test (RAST) Independent Variable: Muscle fatigue index	10 runner athletes	Randomized Controlled Trial	The results showed that post-RAST soymilk intervention significantly lowers the fatigue index, hence, it may be used to improve sports performance requiring anaerobic activity.
Six weeks of Jilin ginseng root supplementation attenuates drop jump-related muscle injury markers in healthy female college students (Chen et al., 2021)	Dependent Variable: Accelerated recovery from muscle fatigue and injury Independent Variable: Administration of jilin ginseng root extract	20 female athletes	Randomized Controlled Trial	Ginseng Root supplementation can reduce drop jump muscle stiffness and fatigue in women.
Effect of tempe drinks on muscle recovery (Malondialdehyde) and sub-maximum activity on sparta DK Percut Sei Tuan football players in Deli Serdang Regency, North Sumatra Province (Winara et al., 2021)	Dependent Variable: Increase in MDA levels Independent Variable: Provision of tempe drink	50 athletes	Randomized Controlled Trial	The result show, the MDA (malondialdehyde) had a significant effect on muscular rehabilition when given tempeh drink.
4-week eicosapentaenoic acid-rich fish oil supplementation partially protects against muscular damage following eccentric contractions (Tsuchiya et al., 2021)	Dependent Variables: EPA and DHA supplementation Independent Variables: Indicator	22 male athletes	Double-blind, placebo-controlled, parallel-design study	3 days after eccentric exercise, there was a significant change in serum Creatin Kinase (CK) ($p < 0.05$)
Impact of varying doses of omega-3 supplementation on muscle damage and recovery after eccentric resistance exercise (Visconti et al., 2021)	Dependent Variables: Independent Variables:	26 male athletes with regular eccentric exercise	Double-blind, randomized, placebo-controlled design	There were significant differences in perceived muscle soreness (PMS), vertical jump height (VJH), and serum creatine kinase after muscle-damaging exercise compared to before exercise ($p<0.05$).
Dose-response effects of dietary protein on muscle protein synthesis during recovery from endurance exercise in young men: a	Dependent Variable: Myofibrillar (MyoPS) and mitochondrial	48 male athletes and non-athletes	Randomized Controlled Trial	Intake 30 g of protein is enough to maximize MyoPS levels when recovery from one round of resistance training. This trial is listed

Title (author, year)	Variable	Study subject	Method	Results
double-blind, randomized trial. (Churchward-Venne et al., 2020)	(MitoPS) postprandial protein synthesis rates Independent Variable: Consumption of carbohydrates with whey, soy, or soy protein			on trial register.nl as NTR5111.
Effects of grape juice consumption on muscle fatigue and oxidative stress in judo athletes: a randomized clinical trial (Goulart et al., 2020)	Dependent Variable: Grape juice consumption Independent variable: Muscle fatigue dan oxidative stress	20 judo athletes	Randomize, double-blind clinical trial	Results are analyzed before and after the game. The grape juice group had greater upper limb strength than the placebo group (p [group] = 0.003).
Effects of leucine-enriched essential amino acid supplementation on muscular fatigue and inflammatory cytokines in wheelchair basketball players (An et al., 2020)	Dependent Variable: Leucine-enriched essential amino acid supplementation Independent variable: inflammatory cytokines	10 wheelchair basketball players who have spinal injuries and have undergone amputations	Double-blind, randomized, crossover study	LEEA supplementation had a significant was the inhibition of circulating IL-6 level in the LEAA-treated group compared to the placebo group ($p<0.05$).
Impact of Varying Dosages of Fish Oil on Recovery and Soreness Following Eccentric Exercise (VanDusseldorp et al., 2020)	Dependent variable: Varying Dosages of Fish Oil Independent variable: Recovery and Soreness	41 male and female athletes	Randomized placebo-controlled double-blind experiment	6G FO supplementation improves recovery of jump performance and muscular soreness aftrer a strenuous workout.
Effect of citrulline on a post-exercise rating of perceived exertion, muscle soreness, and blood lactate levels: A systematic review and meta-analysis (Rhim et al., 2020)	Dependent variable: citrulline on post-exercise rating Independent variable: muscle soreness, and blood lactate level	13 qualified articles	systematic review and meta-analysis	Citrulline supplementation significantly lowered post-exercise rating of perceived exertion (RPE) and muscular pain while having no effect on blood lactate levels.

Title (author, year)	Variable	Study subject	Method	Results
No Effect of New Zealand Blackcurrant Extract on Recovery of Muscle Damage Following Running a Half-Marathon (Costello et al., 2020)	Dependent Variable: Improves recovery from exercise-induced muscle damage after a half marathon race Independent Variable: Administration of blackcurrant extract	20 runner athletes	Randomized Controlled Trial	Perceived muscular pain and fatigue increased immediately after the half marathon ($p < 0.01$) and reverted to pre-half marathon levels within 48 hours, with not significant between group ($p > 0.05$).
Myofibrillar and Mitochondrial Protein Synthesis Rates Do Not Differ in Young Men Following the Ingestion of Carbohydrates with Whey, Soy, or Leucine-Enriched Soy Protein after Concurrent Resistance- and Endurance-Type Exercise (Churchward-Venne et al., 2019)	Dependent Variable: Myofibrillar (MyoPS) and mitochondrial (MitoPS) postprandial protein synthesis rates Independent Variable: Consumption of carbohydrates with whey, soy, or soy protein	36 athletes and non-athletes	Randomized Controlled Trial	During 360 minutes of recovery after exercise, MyoPS and MitoPS levels do not change after consumtion carbs are combined with 20 g of protein from soy, whey, or leucine fortified soy.
Nutritional and Supplementation Strategies to Prevent and Attenuate Exercise-Induced Muscle Damage: a Brief Review (Harty et al., 2019)			A Brief Review	Many emerging nutritional and supplement strategies, including polyphenols sourced, have not been fully explored.
A single dose of purple grape juice improves physical performance and antioxidant activity in runners: a randomized, crossover, double-blind, placebo study (de Lima Tavares Toscano et al., 2020)	Dependent Variables: Physical performance and antioxidant activity Independent Variables: A single dose of purple grape juice	14 runner male athletes	Randomize, crossover, double-blind, placebo study	The group that was given grape juice had a longer travel time than the placebo ($p = 0.008$). This increase in physical performance was followed by a 43.6% ($p=0.000$) Improved in TAC (total antioxidant capacity) at the after exercise compared to baseline values.
Effect of Branched-Chain Amino Acid Supplementation on Recovery Following Acute Eccentric Exercise	Dependent Variables: Independent Variables:	20 male athletes with regular eccentric exercise	Randomize, double-blind, placebo-controlled	There was a significant improved in pain from baseline ($p < 0.01$) in both groups (BCAA (branched-chain amino acid) and placebo) at all time points.

Title (author, year)	Variable	Study subject	Method	Results
(VanDusseldorp et al., 2018)			research design	
Effect of Caffeine Supplementation on Quadriceps Performance After Eccentric Exercise (Green et al., 2018)	Dependent Variable: Effect of recovery on muscle fatigue and injury Independent Variable: caffeine supplementation	16 male and female athletes	Randomized Controlled Trial	The result indicated caffeine has a comparable ergogenic impact on isokinetic torsion in both balanced and injured states. However, it does not affect isometric torsion production, pain perception, or relative fatigue levels.
Green tea extract preserves neuromuscular activation and muscle damage markers in athletes under cumulative fatigue (Machado et al., 2018)	Dependent Variable: Effect of recovery on muscle fatigue and injury Independent Variable: green tea supplementation	16 male athletes	Randomized Controlled Trial	GTE supplementation improved neuromuscular function in response to cumulative fatigue conditions.
Effects of lemon verbena extract (Recoverben®) supplementation on muscle strength and recovery after exhaustive exercise: a randomized, placebo-controlled trial (Buchwald-Werner et al., 2018)	Dependent Variable: lemon verbena (Recoverben®) Independent Variable: Effect of lemon verbena extract (Recoverben®) supplementation on muscle strength	40 healthy males and females	Randomized Controlled Trial	Minimizing muscle breakdown after heavy activity, lemon verbena extract (Recoverben®) has been proved to be a safe and well-tolerated natural sport agent.
Recovery from Exercise-Induced Muscle Damage: Cold-Water Immersion Versus Whole-Body Cryotherapy. (Abaïdia et al., 2017)	Dependent Variable: Cycling time trial performance Independent Variable: Administration of hot and cold ar-therapy	10 male athletes	Randomized Controlled Trial	CWI was more effective than WBC in speeding recovery kinetics for countermovement-jump performance at 72 hours after exercise.
Oral L-citrulline supplementation enhances cycling time trial performance in healthy trained men: Double-blind randomized placebo-controlled 2-way crossover study (Suzuki et al., 2016)	Dependent Variable: Accelerated recovery from muscle fatigue and injury Independent Variable: oral	22 athletes	A double-blind randomized placebo-controlled 2-way crossover study was employed	L-citrulline supplementation significantly increased plasma L-arginine levels and reduced completion time by 1.5% ($p < 0.05$) compared to placebo.

Title (author, year)	Variable	Study subject	Method	Results
	L-citrulline supplementation			
Effect of Moringa Oleifera Leaf Extracts and Honey Supplementation for Performance Physical Fitness Atlet PLPP (Said et al., 2016)	Dependent Variable: Physical fitness (nutritional status) Independent Variable: Administration of kelar leaf extract + honey	40 PLPP athletes	Randomized pretest – posttest design	The two intervention groups had a significant effect, namely an increase in the average nutritional status in the moringa + honey group.
Effect of an herbal/botanical supplement on strength, balance, and muscle function following 12-weeks of resistance training: a placebo-controlled study (Furlong et al., 2014)		24 young adults (16 males, 8 females, avg age = 20,5 ± 1,9 years, weight = 70,9 ± 11,9 kg, height = 176,6 ± 9,9 cm)	A placebo-controlled study	Endurance training improved 1-RM strength ($p < 0.008$), isokinetic strength ($p < 0.05$), and vertical jump height ($p < 0.03$) in the treatment and placebo groups. There were no significant group interactions during were observed over time (all p values >0.10).
Coingestion of protein with carbohydrate during recovery from endurance exercise stimulates skeletal muscle protein synthesis in humans (Howarth et al., 2009)	Dependent Variable: Post-exercise muscle recovery Independent Variable: Coingestion of protein with carbohydrates	48 male respondents	Randomized Controlled Trial	The treatment group that consumes carbohydrates and protein at the time of recovery after aerobic exercise can increase muscle WBNB and FSR compared to those given only carbohydrates.

Fatigue is a non-specific symptom that many individuals commonly experience and associated with their health condition. It can result in decreased work capacity, reduced physical endurance, and difficulty in decision-making (Enoka & Duchateau, 2016; Pignatiello et al., 2020b). Various modulatory factors such as temperature, blood glucose, mood, and fatigue attributes such as performance and perceived fatigue can contribute to the level of fatigue experienced by an individual (Pignatiello et al., 2020a), suhu, dan suasana hati serta atribut kelelahan (Pignatiello et al., 2020a; Enoka & Duchateau, 2016).

Two categories of fatigue are generally recognized, namely mental fatigue which relates to physical fatigue, and cognitive aspects which pertains to motor system performance (Enoka & Duchateau, 2016). Muscle fatigue is an example of physical fatigue characterized by a temporary reduction in strength and skeletal muscle power capacity that results from muscle activity (Wan et al., 2017). This phenomenon typically occurs in athletes due to routine endurance training (Pareja-Blanco et al., 2017) and in individuals engaged in prolonged, strenuous activities, such as hospital porters (Escriche-Escuder et al., 2020).

Muscle fatigue results from decrease activation of motor neurons which govern muscle fibers (Potvin & Fuglevand, 2017). Factors contributing to muscle contraction and fatigue include neuromuscular, sensory, and homeostatic system changes (Taylor et al., 2016). The physiological features of motor units must be considered to understand and identify the causes of muscle fatigue

(Potvin & Fuglevand, 2017). Additionally, reactive factors such as hydrogen ions (H+), inorganic phosphate (Pi), lactic acid, Reactive Oxidative Species (ROS), orosomucoid (ORM), and Heat Shock Protein (HSP) can also have an effect on muscular fatigue (Wan et al., 2017).

Athletes frequently experience muscle fatigue as a result of intensive training. This can lead to increased lactic acid levels in the blood and muscles, causing discomfort and pain due to excessive muscle contractions (Theofilidis et al., 2018). Recovery methods such as stretching and sports massage are often employed to reduce these symptoms (Mulya et al., 2021). This is in addition to certain nutrients to support muscle retention and reduce fatigue levels in athletes. Regular nutritional support is crucial, designed to the athlete's training frequency and duration (Doherty et al., 2019). Although macronutrients remain the primary focus for muscle recovery, non-specific treatments also use micronutrients or nutritional supplements from natural or synthetic sources. Green tea extract and ginseng are among the natural ingredients and extracts claimed to have the potential as anti-muscle fatigue agents (Machado et al., 2018), dan ginseng (Caldwell et al., 2018). The review by Heaton et al. (2017) highlighted the use of certain nutrients to aid muscle regeneration, glycogen recovery, reduce fatigue, and support physical immunity in athletes.

Antioxidant

For centuries, green tea has been a popular beverage and medicinal herb in many Asian countries (Aboulwafa et al., 2019). as it is made from the leaves of Camellia sinensis, which contain beneficial polyphenols, like epigallocatechin gallate, epigallocatechin, epicatechin, and epicatechin gallate. These compounds possess potent antioxidant properties and may help boost immune function (Aboulwafa et al., 2019; Sellami et al., 2018). Recent research also shown that green tea extract may aid in reducing muscle injury and preventing oxidative stress induced by short-term endurance and strength exercises (Jówko et al., 2015). Another study supported using green tea extract to improve neuromuscular function in response to cumulative fatigue (Machado et al., 2018).

Ginseng is a popular herbal supplement with antioxidant properties and boosts the immune system (Jówko et al., 2015). Preliminary studies also showed that ginseng can reduce post-resistance exercise soreness and pain in athletes for up to 24 hours (Caldwell et al., 2018). Red ginseng, a specific type of ginseng, has positively impacted athletic performance (Wan et al., 2017). However, ginseng may also cause side effects, such as diarrhea, insomnia, and arrhythmia (Potvin & Fuglevand, 2017). Despite its potential benefits, it is important to be aware of these side effects when considering using ginseng.

The study conducted by Lamou highlighted the potential benefits of *Moringa oleifera* Lam leaves extract supplements as anti-fatigue agents for athletes, in addition to green tea and ginseng. The leaves also contain several bioactive compounds, such as phenolic compounds, which can enhance muscle protein functional properties (Lamou et al., 2016). combination of *M. oleifera* leaves and honey can improve the physical fitness of athletes, with statistically significant improvements observed (21.21 ± 1.40 and 20.81 ± 1.34, $p<0.05$)(Said et al., 2016).

Previous study suggested that consuming polyphenols derived from fruits, such as grapes, may aid in reducing fatigue and enhancing athletic performance, most likely because of their anti-inflammatory and antioxidant effects (Xianchu et al., 2018). Goulart (2020) administered 400 ml of grape juice to judo athletes for 14 days and found that it reduced muscle pain and increased oxidative stress biomarkers. Similarly, Toscano's study demonstrated that one serving of purple grape juice intake improved athletic performance during running as wll as increased antioxidant activity due to its ergogenic effect (de Lima Tavares Toscano et al., 2020). Another study found that dragon fruit juice could to minimze the growth in the number of leucocytes following high-intensity exercise (Alginda, 2020).

Caffeine

Mielgo-Ayuso demonstrated that synthetic products such as caffeine can impact aerobic and anaerobic activity, as well as fatigue index in male and female athletes (Lamou et al., 2016). In contrast, Loureiro supported previous findings by examining the effects of coffee consumption after strenuous exercise on muscle glycogen resynthesis and glycemic response. The study found that adding coffee to a carbohydrate-containing beverage can improve muscle glycogen resynthesis as well as glycemic and insulinemic responses in athletes during a 4-hour recovery period after strenuous cycling exercise (Loureiro et al., 2021). Similarly, Green's study also supported the notion that caffeine can aid in muscle

fatigue recovery by demonstrating its ergogenic effects on isokinetic torque in non-injured and injured conditions (Reen et al., 2018).

Sitrullin

A meta-analysis and systematic review supported the effectiveness of citrulline supplements in reducing the rating of perceived exertion (RPE) and muscular soreness. L-citrulline alone or CM can benefit from 1 hour before exercise athletes by combating fatigue or relieving muscular soreness. Strength and power athletes are particularly advised to take citrulline supplements to ensure adequate recovery and enable them to workout at the intensity level desired. However, further research is needed to confirm the efficacy of citrulline supplementation in endurance athletes (Rhim et al., 2020).

Several nutrition and supplement solutions have been identified by studies, with varied degrees of success. Based on preliminary clue, long-term intake of antioxidant-rich foods such as tart cherry juice, beetroot juice, watermelon juice, and pomegranate, as well as certain chronic supplementation option including omega-3 polyunsaturated fatty acids, creatine, and vitamin D3, might help minimize muscle damage symptoms resulting from exercise and enhance muscle function across different populations (Harty et al., 2019).

Amino Acid

Amino acid supplements, specifically BCAAs, are commonly used by athletes to promote synthesis and aid in muscle recovery (Martínez Sanz et al., 2019). Such supplements are effective not only for athletes without disabilities but also for those with physical disabilities (An et al., 2020; Shaw et al., 2021). Patterson claimed that consuming BCAA or isolated leucine can accelerate muscle fatigue recovery by protecting and regenerating passive contractile elements and structural in the muscle and reducing combined muscle soreness. Additionally, twice daily, BCAA supplementation at a dose of 0.087 g/kg body mass (1:1:2 valine, isoleucine, and leucine) has been shown to improve performance in multi-joint activities such as counter-movement jumps (Patterson et al., 2019). These findings are supported by VanDusseldorp's study, indicating that BCAA supplementation reduces soreness after eccentric exercise in athletes (VanDusseldorp et al., 2018).

Omega-3

Several studies suggested that fish oil can positively improve exercise performance and muscle recovery. supplementation with Omega-3 polyunsaturated fatty acid is presently considered an ergogenic aid for athletes (Thielecke & Blannin, 2020). Preliminary studies showed that taking 6 g of fish oil can optimize muscle soreness recovery after heavy exercise (VanDusseldorp et al., 2020). while a daily dose of 250-500 mg/day is recommended (Murphy & McGlory, 2021). However, a higher dose of 8 g did not appear to improve muscle recovery following eccentric resistance exercise (Visconti et al., 2021). Tsuchiya's study found that shorter-term (4 weeks) fish oil supplementation can benefit joint flexibility and muscle fiber protection after eccentric exercise (Tsuchiya et al., 2021).

CONCLUSION

In order to combat muscle fatigue in athletes, natural ingredients and synthetic nutritional supplements have been utilized as dietary interventions. This literature review identified numerous natural micronutrients and synthetic supplements used in sports that possess anti-fatigue properties, decrease oxidative stress, and enhance athletes' endurance capacity.

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