Role of Supplements and Ergogenic Aids in Sports and Exercise

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Abstract

Supplements and ergogenic aids (EA) have gained significant popularity in sports, with athletes utilizing them more frequently thanthe general populace. While supplements are concentrated sources of nutrients that produce physiological effects similar to a typical diet, EA are pharmacological drugs designed to enhance athletic performance. We classify sports supplements into three categories: sports nutrition, medicinal supplements, and performance supplements. Two ergogenic agents that can improve athletic performance are caffeine and creatine monohydrate. Performance gains are commonly associated with caffeine intake of 3-6 mg/kg of body weight, 60 minutes before exercise. By raising muscular creatine and phosphocreatine levels, creatine monohydrate prolongs exercise duration. β-Alanine supplementation improves tolerance for maximal activity durations of 30 seconds to 10 minutes, resulting in small but possibly considerable performance enhancements. Contrary to common perception, sports supplements may include substances forbidden by WADA, resulting in inadvertent doping and possible health risks. inadequate quality control during manufacture may lead to inconsistencies in active ingredients, while tainted and contaminated sports supplements might inadvertently subject professional athletes to doping violations and pose serious health risks.

Keywords: Ergogenic aids, Sports food, Supplements, Exercise, Nutrients

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Introduction

In the sports industry, ergogenic aids (EA) and nutritional supplements (NtS) have become increasingly popular. The utilization of supplements is prevalent in athletics. The literature reviews indicate that supplement usage is more common among athletes (about 50%) than the general population (35-40%), with nearly 60% of elite athletes reporting supplement consumption. All these surveys indicate that the overall incidence and types of supplements utilized differ according to the sport's nature, the athletes' gender, and the competition level. In certain surveys, all bodybuilding and strength-training athletes utilize some type of nutritional supplement. While EA are pharmaceutical medications used to improve athletic performance, NtS are concentrated sources of nutrients or chemicals that have physiological or nutritional effects comparable to those of a typical diet (Lopez-Samanes et al., 2015).

High-performance athletes and college students represent a profitable market for commercial brands (Gómez -Urquiza et al., 2015), and young amateur athletes (Parnell et al., 2015) people enthusiastically use these products to improve their diets. The health and sports authorities are concerned about the increasing use of nutritional supplements (NtS) and ergogenic aids (EA) among athletes, given that a significant portion of these products contain hazardous or prohibited ingredients. If it contains doping medications, this could endanger the athlete's health or result in a suspension from competition (Pallarés et al., 2015). Only a few ergogenic aids (EAs), such as creatine, sodium bicarbonate, and caffeine, have been demonstrated to improve sports performance, even though nutritional supplements (NtS) and EAs are frequently used at all levels of athletic performance. A list of nutritious substances as described by López -Samanes et al. (2017) with examples is provided in Table 1.

Table 1: Nutritional Compounds and their Examples of Supplements in Sports (Gunes-Bayir & Cemberci, 2023)

Compounds	Exemples
Amino acid and protein	Casein protein, whey protein, soy protein, aspartate, arginine, BCAAs, creatine, carnitine, glutamine, lysine, glucosamine, ornithine, b-hydroxy-b-methyl butyrate
Oil	Omega-3 and medium chain triglycerides
Mineral and vitamin	Calcium, beta-carotene, iron, vitamin B, vitamin C and E
Sports drink	Milk, juice, energy drink, isotonic drink, hypertonic drink, hypotonic drink
Other substances	Caffeine, coenzyme Q10, carotenoids, antioxidants, ginseng, tannins, taurine

Adequate hydration and concurrent consumption of macronutrients and micronutrients are essential for the preservation and enhancement of athletic performance before to, during, and following exercise. We are aware that ergogenic aids are used to enhance athletic performance, avoid injuries, and speed up the recovery process after exercise (Gunes-Bayir & Çemberci, 2023). In this context, body deficiencies are addressed and the proper ergogenic body mass is tailored to particular sports. These substances comprise naturally consumed nutrients from regular nourishment and are usually in the form of pills, gels, powders, or liquids. Consuming micro and macronutrients that balance energy and hydration is one of the many dietary components necessary to improve and maintain performance during exercise (Switala, 2023). The ergogenic aids are frequently preferred by athletes to improve strength and endurance, rapidly reach particular performance objectives, and avoid any injuries. These aids include materials or techniques such as certain vitamins, minerals, botanicals, amino acids, metabolites, and different combinations of these. To guarantee proper energy, system balance, lean body mass, and muscle growth, these medications or treatments are added to athletes' diets (Gunes-Bayir & Çemberci, 2023).

2. Types of Supplements

The sports supplements fall into three categories: medical supplements, which may be necessary to prevent or treat nutrient deficiencies in athletes; sports foods, which provide a convenient means of achieving sports nutrition goals; and the more general category of performance supplements, which claim to either directly increase exercise capacity or facilitate activities that enable athletes to train hard, recover, reach physical goals, or reduce their risk of illnesses and injuries (Bucci, 2022).

The supplements might provide supplementary benefits or directly improve exercise performance. Perhaps the most reliable sports supplements are sports meals and medical supplements, especially when made by reliable businesses and used in compliance with best practices catered to the particular athlete and their situation (Silano et al., 2011). The medical supplements can be used to treat or prevent vitamin deficiencies, which can occur more frequently in some athletes or negatively affect adaptation and performance, even at subclinical levels in populations that are not active. Iron deficiency may happen more often because exercise raises the iron-regulating hormone hepcidin, which makes it harder for the body to absorb iron from food and recycle it by macrophages. The sports meals offer a convenient means to obtain targeted nutrients, particularly in exercise-related situations where the eating of regular foods may be impracticable. Despite the seemingly settled nature of items in these categories, knowledge and practice persist in their evolution. The recent findings indicate that daily iron supplementation, initiated before altitude training, is essential to enhance current iron reserves and optimize the intended hematological responses to this regimen, even in non-anemic athletes (Méndez-Navarro et al., 2012). Table 2 describes the supplements categorization by their usage.

Table 2: Use-Based Supplement Categorization (Garthe & Maughan, 2018)

Category	Examples	Comments
Sports food: Sports food are specialized goods that offer a useful source of nutrition when regular meals are not feasible.	Drinks, gel, confectionery, bar, liquid meal	The majority of sports snacks, but not all, are unlikely to contain illegal ingredients.
Medical supplements: Used to address medical conditions, such as identified dietary deficits.	Calcium, iron, vitamin D, multivitamin/mineral, probiotic (gut/immune)	The majority of vitamin and mineral supplements that are bought from pharmacies are made under stringent pharmaceutical control, but not all of them are.
Ergogenic supplements: supplements to enhance performance.	Alanine, caffeine, creatine, bicarbonate, β-alanine, nitrate (beetroot juice)	Ergogenic supplements that are not prohibited by the World Anti-Doping Agency (WADA) use concentrated forms of substances that are present in food. Intentional adulteration through the use of pharmaceutical drugs is a possibility, as is cross-contamination with hazardous or unlawful chemicals.
Functional food and superfoods: allegedly to maximize performance and well-being	Berry and raw juice, (acai, goji extracts, natural alkalizing fruits, seeds (chia seeds), plant fibers, spirulina organic foods, seaweeds, herbs	There is no assurance regarding the quantity of biologically active material. Biologically active chemicals are difficult to identify and classify due to product variability. Chinese, Korean, and/or herbal medicine prescriptions are the main sources of herbal or traditional items, such as plant and animal ingredients. Governmental rules and regulations vary from nation to nation.
Other supplements: include a wide range of herbal and botanical extracts and concentrates.	Supplements for the prevention of hair loss, enhanced libido, enhanced energy, and weight loss (shakes, tablets)	may consist of central nervous system stimulants (e.g., ephedrine) and hormones or hormone precursors (e.g., norandrostenedione and norandrostenediol). They are said to have a significant risk of adulteration since the consumer needs to see results fast to motivate continued use of the product. Strong drugs are sometimes used by manufacturers to achieve these effects.

The five types of ergogenic aids are mechanical or biomechanical, psychological, pharmacological, physiological, and dietary (Gunes-Bayir & Çemberci, 2023). An individual's performance, strength, production, and accomplishment are all intended to be enhanced by these methods or agents. The mechanical domains of exercise and sports equipment, footwear, clothing, and vehicles; the physiological domains of massage and sauna; the pharmacological domains of stimulants and energy-boosting medications; and the psychological and motivational domains of psychological and nutritional supplements that promote muscle mass and improve overall health are all examples of its presence (Cagıran, 2020). Figures 1 and 2 describe a few sports foods, medical supplements, and performance substances, respectively.

Table 3: Categorization of Sports Supplements According to their Effectiveness (Porrini and Del Bo', 2016)

	Sports Food	Performance Enhancing Supplement	Muscle Building and Repair Supplements
Apparently Effective	Carbohydrate-electrolyte-based drinks, bars, powder, carbohydrate or protein-based drinks, bars, powder	Sodium bicarbonate Sodium citrate Caffeine Creatine	
Possibly Effective		Amino acids Branched-chain amino acids Essential amino acids HMB	Branched chain amino acids HMB Essential amino acids Leucine
Too Early to Tell		Medium chain triglycerides (MCT)	α-ketoglutarate
Apparently Ineffective		Ribosine Chromium l-Carnitine Glutamine Inosine	Boron Glutamine Conjugated linoleic acids Chromium Isoflavones

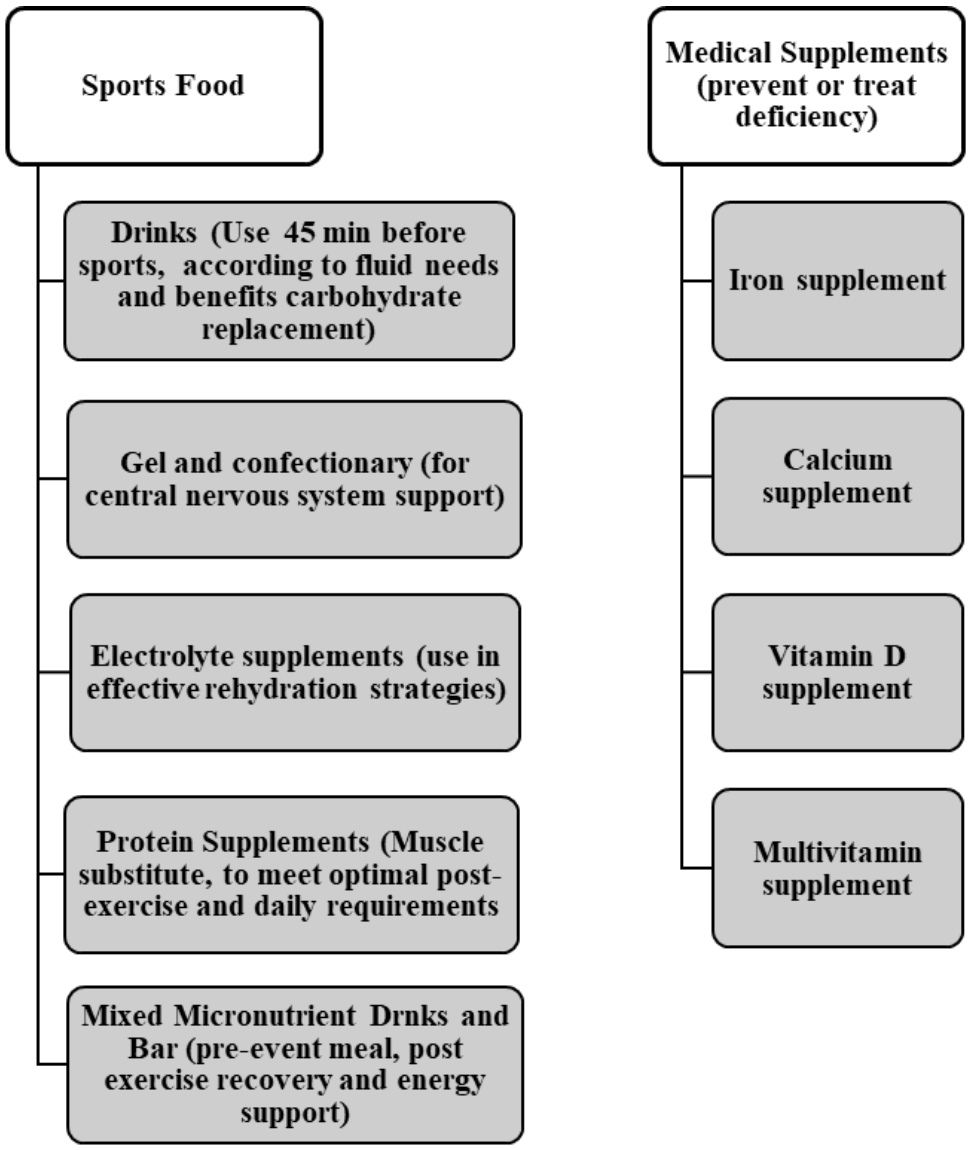

Fig. 1: An overview of athletes' evidence-based use of medical supplements and sports meals (Word)

3. Mechanism of Action

Table 4 defines the methods of action of various food substances. The action mechanism of supplements involves stimulating the central or peripheral nervous system, which includes lowering or neutralizing metabolic byproducts that induce fatigue and enhancing recovery post-exercise (Gunes-Bayir & Çemberci, 2023).

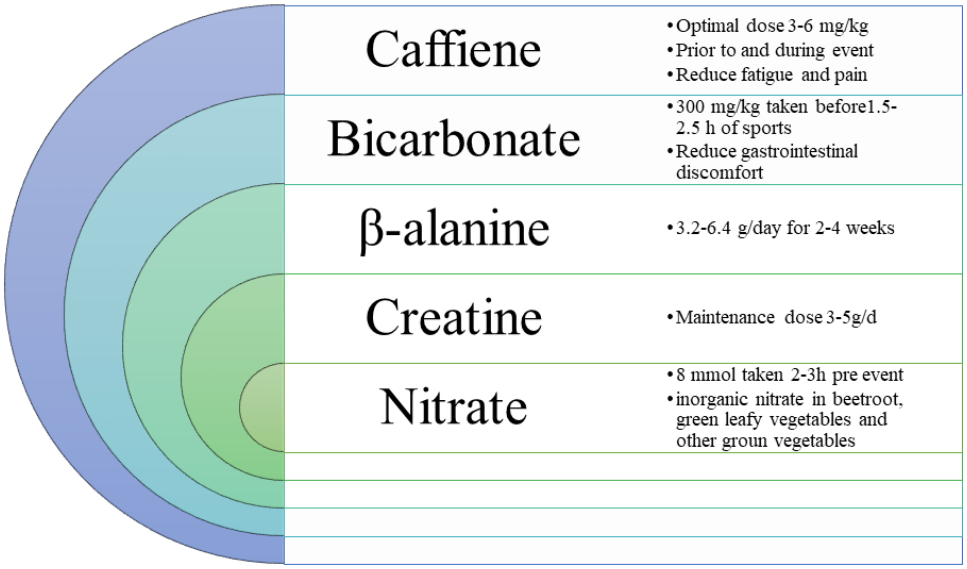

Fig. 2: Performance enhancers that directly improve athletic events and exercise (Word)

Table 4: Method of Action of Various Substances (Gunes-Bayir & Çemberci, 2023)

Mechanisms	Examples of Supplements
Supplying a substrate for energy	Carbohydrates: Energy source for aerobic glycolysis
	Creatine: Synthesis of phosphocreatine
Generating energy to develop metabolic pathways	B vitamin: Glycolysis coenzymes
	Iron: Transport and use of oxygen
Improves the performance of the respiratory and cardiovascular systems	Glycerol: Increased blood volume
	Sympathomimetics: Increases bronchodilation
Expand the quantity or size of cells that generate energy.	Anabolic steroids: Expand the size of muscle cells
	Erythropoietin: Red blood cell counts are raised
Decrease the metabolic byproducts linked to exhaustion	Sodium bicarbonate: Lactic acid buffer
	Aspartate salts: Decrease the buildup of ammonia
Suppress the degeneration of cells that provide energy	Antioxidants: Lipid peroxidation is prevented
	Ginseng: Adaptogens that lessen physical stress

3.1. Caffeine

In both endurance events and short-duration, supramaximal activities, caffeine significantly improves athletic performance. When consumed at levels of 3–6 mg/kg of body mass, approximately 60 minutes before exercise, anhydrous caffeine, which is available as pills or powder, is frequently associated with enhanced performance (Ganio et al., 2009). The lower caffeine dosages (<3 mg/kg BM, around 200 mg) have been shown to have a comparable ergogenic effect when taken both before and during exercise (Spriet, 2014). The recent research suggests that an athlete's genetic variants, namely those related to the CYP1A2 gene, which is involved in the liver's metabolism of caffeine, may have an impact on the ergogenic effects of caffeine (Garthe & Maughan, 2018).

In addition to confirming the necessity for athletes to test out their intended performance applications of caffeine before the competition, this clarifies the recognized variation in individual responses to social caffeine consumption. They should also consider their responses to caffeine consumption in their daily lives, such as effects on heart rate, jitteriness, or sleep quality. Instead of improving performance effects, the higher caffeine dosages (≥9 mg/kg BM) are more likely to increase the chance of unpleasant side effects like nausea, anxiety, sleeplessness, and restlessness. It seems that caffeine habituation has minimal effect on the stimulant's capacity to enhance performance (Goldstein et al., 2010). The performance benefits of regular high-caffeine consumption are often comparable to those of regular low-to-moderate caffeine consumption (de Souza Gonçalves et al., 2017). Athletes can also enhance their performance without experiencing "caffeine withdrawal" in the days before competition, according to studies. Instead of a clear benefit (see Table 3), previous research assessing the mitigation of the adverse effects of caffeine withdrawal might have discovered a greater improvement in performance following supplementation following a period of dehabituation e.g., demotivation, fatigue, headache (Irwin et al., 2011) in addition to the typical performance enhancement.

Studies on caffeine supplementation provide compelling evidence of enhanced performance when taken before five to one hundred and fifty minutes of activity (Ganio et al., 2009). Additionally, studies have demonstrated that ingesting 100–300 mg of caffeine before engaging in endurance exercise and then exercising for 15–80 minutes increases endurance performance by 3-7% (Paton et al., 2015; Talanian & Spriet, 2016). The caffeine dosages of 3-6 mg/kg body mass 50-60 minutes before exercise produce performance increases of greater than 3% for anaerobic exercises lasting 1-2 minutes when short-term, supramaximal tasks are performed. Therefore, it is recommended that high-performance track and field athletes who compete in middle-distance, endurance/ultra-endurance, and longer sprints think about consuming coffee during competition. Certain activities may also benefit from redistributing caffeine consumption to coincide with training sessions, especially when practicing competitive scenarios or during sessions when you're tired (Lane et al., 2013).

3.2. Creatine Monohydrate

The muscles retain more creatine and phosphocreatine when creatine monohydrate (CM) supplements are used. This makes exercise last longer because the body can't make enough phosphocreatine to meet its energy needs. This is especially true for short-term high-intensity efforts that last less than 150 seconds, with the biggest effects seen in activities that last less than 30 seconds (Lanhers et al., 2017). In 1992, after the first study on efficient loading procedures was published and anecdotal evidence of its use by British track and field gold medalists at the Barcelona Olympics surfaced, creatine supplementation became a major topic. The long-lasting training adaptations have also been suggested via both direct and indirect processes, including increases in lean mass and muscular strength and power. Because increased creatine and water retention alter the cellular environment, it has been proposed that endurance athletes benefit from improved thermoregulation and glycogen storage (Cooper et al., 2012; Kreider et al., 2017). However, in light of event-specific performance needs, it is vital to evaluate the possible adverse effects of a slight weight gain brought on by these mechanisms (see Table 3).

A "maintenance phase" that typically consists of a single daily dose of 3-5 g throughout the remainder of the supplementing period follows a "loading phase" of roughly 20 g/day (split into four equal doses of 5 g each) that lasts for 5-7 days. These are typical examples of effective supplementation strategies. For roughly four weeks, several approaches advise administering lesser doses of creatine monohydrate (2–5 g/day) (Rawson et al., 2011), founded on the hypothesis that muscle creatine levels might be raised by administering tiny doses of creatine monohydrate for an extended period. Notably, by raising insulin levels, consuming a combination of protein and carbohydrates (about 50 g each) with creatine monohydrate may enhance the absorption of creatine in muscles (Peeling et al., 2018). Additionally, muscle reserves take about 4–6 weeks to return to baseline levels when supplementation is stopped.

As long as adequate loading procedures are followed, long-term use of CM (up to 4 years) has not been associated with any adverse health effects; in certain cases, it may even have anti-inflammatory qualities (Deminice et al., 2013). As a result, using creatine supplements as previously mentioned significantly enhances performance over the short and long term, especially in power, strength, and brief, repeated high-intensity workouts.

3.3. Nitrate

It has been shown that taking nitrate supplements improves performance in aerobic competitions lasting less than 40 minutes (1-3% improvement in performance) and time to exhaustion (4-25% increase in performance) (Jones, 2014; McMahon et al., 2017). Bailey et al. (2015) claim that using nitrate supplements may enhance Type II muscle fiber function, resulting in a 3-5% increase in high-intensity exercise performance (Thompson et al., 2015; Wylie et al., 2016). More research is required in this area because the data currently available does not adequately demonstrate the benefits of exercise tasks that last less than 12 minutes (Reynolds et al., 2016; Thompson et al., 2016).

Although foods high in nitrates include leafy greens and root vegetables including spinach, arugula, celery, and beetroot, beetroot juice is the suggested supplement for use during exercise (McMahon et al., 2017). According to Hoon et al. (2014) and Peeling et al. (2018), a nitrate bolus of 5-9 mmol (310-560 mg) typically produces acute performance gains in 2–3 hours; however, extended nitrate consumption (>3 days) also seems to be advantageous for performance. (Thompson et al., 2015, 2016).

The nitrate supplementation seems to have few limitations or negative effects, with the possible exception of mild gastrointestinal discomfort in those athletes who are sensitive to their stomachs. Additionally, a threshold for the benefits of NO_3 consumption was set by Wylie et al. (2016), who found no discernible difference between 16.80 mmol [1,040 mg] and 8.40 mmol [520 mg]. It's also critical to recognize that elite athletes frequently see little to no improvement in their performance, especially when their maximal oxygen consumption (VO_2max) surpasses 60 ml/kg (Jones, 2014). Therefore, it is best to test this supplement individually before using it in competition to ensure that it works.

3.4. β-Alanine

Supplementing with β-Alanine improves tolerance for maximal exercise lasting 30 seconds to 10 minutes, resulting in modest but potentially significant performance gains (about 0.2–3%) in both continuous and intermittent exercise activities of this length (Baguet et al., 2010; Burke et al., 2012; Saunders et al., 2017). The carnosine levels are higher in muscles that take in more β-alanine. Carnosine is an intracellular dipeptide that has anti-inflammatory, antioxidant, and buffering properties. Improved buffering is the primary performance advantage. For prolonged duration of 4-12 weeks, β-Alanine dosage recommendations usually recommend 3.2-6.4 g per day, administered in divided doses (0.8-1.6 g every 3-4 hours). The researchers have not yet established a clear connection between the degree of muscle carnosine alteration and enhanced performance (Saunders et al., 2017). Well-trained athletes have demonstrated the efficacy of this supplement (Bex et al., 2014; Saunders et al., 2017), albeit with noticeably diminished potential for performance enhancement (Bellinger, 2014). One potential adverse effect of cutaneous paraesthesia should be acknowledged; however, prolonged-release tablets are recognized for mitigating this issue and are said to decrease urinary excretion of the supplement, potentially enhancing overall β-alanine retention in the body (Décombaz et al., 2012). Supplementing with β-alanine has been shown to cause significant interindividual variability in muscle carnosine synthesis (Stautemas et al., 2018), which calls for a personalized supplementation strategy.

3.5. Sodium Bicarbonate

Short-term, high-intensity sprints lasting around 60 seconds show a 2% improvement in performance with sodium bicarbonate ($NaHCO_3$) supplementation, but the effectiveness diminishes as the effort length approaches 10 minutes. The $NaHCO_3$ ingestion (at a dosage of 0.2-0.4 g/kg body mass) causes a rapid increase in extracellular/blood buffering, in contrast to β-alanine supplementation, which results in a sustained enhancement of intracellular buffering capacity (Carr et al., 2011). The maximum blood bicarbonate concentrations were observed 75-180 minutes post-consumption (at 0.3 g/kg body mass $NaHCO_3$), and they then declined three hours after supplementation (Jones et al., 2016). Nonetheless, methods to lessen the known gastrointestinal discomfort associated with this supplement have been proposed, including split doses (i.e., several smaller doses) spaced out over 30 to 60 minutes (Krustrup et al., 2015) or serial loading with three to four smaller doses per

day for two to four days before an event (Burke, 2013). Other strategies to reduce gastrointestinal distress include taking $NaHCO_3$ concurrently with a moderately high-carbohydrate meal (about 1.5 g/kg BM CHO) (Carr et al., 2011) or using sodium citrate, which is less effective but more gastrointestinal-friendly.

4. Health Concern Related to Supplements and Ergogenic Aida

Certain sports supplements may include WADA-prohibited chemicals, including unlisted performance-enhancing pharmaceuticals (Rocha et al., 2016; Martínez-Sanz et al., 2017). Unintentional doping happens as a result of the high usage rates. Affirmative anti-doping test results resulting from the use of supplements containing drugs that are not declared by anti-doping organizations and regulations, such as the World Anti-Doping Agency (WADA), are referred to as unintentional doping. Additionally, these supplements might contain botanical chemicals that have never been used by humans before, which are frequently employed as cover-ups for the inclusion of illegal narcotics (Jędrejko et al., 2021).

Inadequate quality control throughout the manufacturing process causes variations in the amount of active ingredients in a supplement. However, there is evidence that certain goods do not include the amount of the highest-value ingredients indicated on the label; in some cases, the active ingredient is completely missing and the product is made entirely of inexpensive substances. Furthermore, even reasonably priced substances could be absent or only present in trace amounts (Maughan et al., 2013). The cross-contamination of supplements on the same production line can occur due to inadequate manufacturing processes, but this is frequently done on purpose by the producers to obtain the more noticeable effects that their products are supposed to have (Odoardi et al., 2015). The supplements that are purposefully infused with illegal substances or pharmacologically active ingredients that are not listed on the nutritional label are referred to as contaminated supplements (Ronis et al., 2018). These supplements have the potential to cause problems by exposing professional athletes to unintentional doping and posing significant health risks to consumers due to the inadvertent consumption of pharmacologically active chemicals. The concerns go beyond the inherent risks of excessive medication consumption, polypharmacy, and the lack of human evaluation of some medications, leaving the effects of their combination with exercise uncertain (Mathews, 2018).

Little evidence of negative effects has left the health effects of tainted and/or falsified sports supplements unclear. Furthermore, some adverse effects could not show up right away but instead develop into long-term, lasting health problems (Eichner and Tygart, 2016). It's hard to put together data from case reports of bad things happening because of tampered sports supplements because there isn't enough information available, like the names of the products or the companies that made them. Some factors make the data hard to understand, like drug addiction, taking other medications at the same time, and other risks that people already know about. Product identification and quality are the primary determinants of report reliability; however, reports often inadequately identify, analyze, or characterize most supplements, which complicates product attribution (Muñoz -Maldonado et al., 2022). Additionally, most patients do not report using supplements, which makes it more difficult for doctors to identify associated side effects as often as they can with medications. Potential knowledge gaps on drug-supplement interactions exacerbate this issue even more (Geller et al., 2015).

It is well known that purchasing sports supplements is beneficial. The easy availability of sports supplements through the internet, supplement stores, and gyms without requiring a prescription or clinical recommendation is largely responsible for their widespread use. Additionally, because of increased consumer demand, the number of supplements sold on the black market has increased dramatically in recent decades (Odoardi et al., 2015). There is a serious chance that sports supplements, like those that boost muscle mass, will be contaminated or contaminated (Pomeranz et al., 2015; Kulkarni et al., 2017).

Conclusion

Even if there is strong evidence that these supplements are beneficial for well-trained athletes, it is still vital to take individual tolerance and any adverse effects into account. Thus, it is essential to thoroughly evaluate any supplement before competition and during training. The usage of these supplements in track and field competitions does, however, present some potential challenges, such as worries about repeated use and the potential for interactions when using many potentially helpful supplements at once. The literature currently available on this use needs to be thoroughly examined.

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