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Examining the Effects of Probiotics on Athletes: A Review

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Abstract

Introduction and Objective. Probiotics, defined as live microorganisms that provide health benefits when consumed in sufficient quantities, have gained attention in the sports community. The surge in popularity of long-distance athletic competitions such as marathons, triathlons, and cycling races has led to heightened rivalry and a rising curiosity in strategies to improve sports performance. Studies have suggested that probiotics could be a valuable aid for athletes looking to improve their well-being and overall progress.

Methods. A literature review was conducted using PubMed and Google Scholar with search terms like "probiotics", "gut microflora", "probiotics in sport", "human microbiome", "athletic performance", "human microbiome", “diet supplementation” and related variations. Articles published within the last five years were prioritized.

Brief description of the state of Knowledge. Probiotic supplementation has been shown to positively impact the health and performance of athletes, primarily through modulation of the microbiota-gut-brain axis. This review examines the influence of probiotic supplements on athletic performance, focusing on their effects on gut microbiota, immune support, mental health, anti-inflammatory properties, and overall performance enhancement.

Conclusions. Probiotics have been found to have numerous health benefits within the microbiota-gut-brain axis, making them an emerging area of research in athletes. The aim of this research is to understand the potential impacts on athletes experiencing health issues such

as gastrointestinal symptoms, lowered immune system, mental disorders, excessive inflammation, or those looking to improve endurance and performance.

Keywords: probiotics, gut microflora, probiotics in sport, human microbiome, athletic performance, diet supplementation.

Introduction and Objectives

The human microbiome is a complex ecosystem consisting of a diverse array of microorganisms such as bacteria, archaea, viruses, and eukaryotes that reside both within and outside of our bodies. These microorganisms play a crucial role in shaping human physiology, affecting metabolic and immune functions in both health and disease states [1,2,3]. In recent years, there has been a growing interest in the role of the microbiota in promoting overall health [4]. The World Health Organization and the Food and Agriculture Organization of the United Nations have defined probiotics as live microorganisms that, when consumed in adequate amounts, confer health benefits on the host [5]. Probiotics can be consumed in various forms, including incorporation into foods or drinks (such as dairy or non-dairy products) or as supplements [6]. In order to enhance the growth and activity of probiotics there is need to apply prebiotics. [7]. The International Scientific Association for Probiotics and Prebiotics (ISAPP) defines prebiotics as substrates that are selectively utilized by host microorganisms, conferring a health benefit [8]. Public awareness and acceptance of probiotics and prebiotics continue to grow, with the probiotic industry expected to expand at a rate of 7% annually, while prebiotics are projected to experience a 12.7% growth over the next eight years. [9]. For athletes, who often experience increased physical stress, dietary changes, and a higher risk of gastrointestinal disturbances due to intense training and competition, the benefits of probiotics are particularly relevant. Endurance sporting events such as marathons, ultramarathons, triathlons, and cycling events have seen a surge in popularity in recent years, leading to increased competitiveness and a greater emphasis on finding ways to improve performance [10]. The use of probiotics as a dietary supplement for athletes is becoming

increasingly common. Research suggests that they may help support immune function, improve nutrient absorption, and aid in recovery from exercise-induced stress [10,11]. As athletes strive for peak performance, the potential benefits of probiotics in promoting gastrointestinal health and overall well-being are being recognized as valuable tools in their training regimens [10,12].

Methods

A literature review was conducted using PubMed and Google Scholar with search terms like "probiotics", "gut microflora", "probiotics in sport", "human microbiome", "athletic performance", "human microbiome", “diet supplementation” and related variations. The focus was on clinical trials, double-blind randomized controlled trials, meta-analyses, systematic reviews, and other review articles. Priority was given to articles published within the last five years to ensure that the review captured the most up-to-date research in this rapidly evolving field. Case reports were not included in the review.

State of knowledge

Gut health in athletes. Gut health and immune function are crucial factors for athletes in maintaining their performance levels [12,13]. However, lower gastrointestinal tract symptoms are commonly reported among athletes and pose a significant challenge. These symptoms include lower abdominal cramping, the urge to defecate, increased bowel frequency and diarrhea [14,15]. It has been noted that up to 71% of runners experience these symptoms either during or after a run [15]. Interestingly, long-distance running is often associated with lower gastrointestinal symptoms, while cycling is linked to both upper and lower symptoms. Triathletes further confirm this pattern, experiencing symptoms during both cycling and running [15]. One potential solution for improving gut health and immune function in athletes is the use of probiotics [12]. Probiotics can have a positive impact on the human body through several key mechanisms, including competitive exclusion of pathogens, enhancement of intestinal barrier functions, modulation of the immune system, and production of neurotransmitters. By competing with pathogens for nutrients and receptor-binding sites in the gut, probiotics can hinder the survival of harmful bacteria [16]. Moreover, the intake of probiotics by healthy individuals has been shown to result in improvements in levels of essential nutrients such as vitamin B12, folate, calcium, zinc, and iron [17]. Therefore, the beneficial mechanisms of probiotics offer a promising approach to addressing the high

prevalence of gastrointestinal symptoms among athletes. By incorporating probiotics into their diet, athletes may be able to improve their gut health, enhance their immune function, and ultimately optimize their performance levels [12].

Influence on the immune system. The intricate interplay between immune cells and commensal microbes in the human intestine is crucial for maintaining a healthy immune system. This dynamic communication occurs in a stable environment, where probiotic bacteria play a key role in stimulating and interacting with both immune cells and commensal microflora [18]. Probiotics have been found to modulate specific immune functions and immune homeostasis in the intestine by activating and modifying innate and adaptive immune responses. They achieve this by inducing the production of various cytokines and chemokines from different immune cells, including dendritic cells, lymphocytes, macrophages, mast cells, granulocytes, and intestinal epithelial cells. Additionally, probiotics promote the generation of IgA-producing cells, leading to enhanced IgA secretion [18,19, 20,21,22]. In the context of heavy training schedules or endurance competitions, athletes often experience immunodepression due to extreme physical stress, making them more susceptible to infections, especially upper respiratory tract infections (URTI) [23]. Clinical trials have demonstrated the potential of probiotics as preventive and therapeutic agents against upper respiratory tract infections (URTIs) and otitis [24]. Probiotics possess unique mechanical properties that enable them to aggregate, compete with pathogens for nutrients and space, and prevent pathogens from attaching to host cells. By directly antagonizing pathogens, probiotics can exert beneficial effects without altering the host's metabolism [24].

Impact on mental health. The International Olympic Committee (IOC) acknowledges the importance of mental health in the overall well-being and performance of elite athletes, recognizing that it is closely linked to physical health [25]. Over a follow-up period of up to 12 months, it has been reported that mental health disorders affect up to 35% of elite athletes [25]. Research has also highlighted the potential impact of gut microbiota on the mental health of individuals dealing with depression and anxiety [26]. The microbiota-gut-brain axis, a bidirectional signaling pathway between the central nervous system and the gastrointestinal tract, plays a crucial role in this relationship. Evidence suggests that the composition of intestinal microbiota can influence neurological and mental health conditions, with

interactions between gut bacteria and the intestinal epithelium affecting brain function, mood, and behavior [26]. Furthermore, interventions such as probiotics, prebiotics, and dietary modifications have shown promise in improving mood, reducing anxiety, and alleviating symptoms of depression in individuals with mental health disorders [27]. These alternative treatments may be preferred over traditional medication due to their potential side effects [28]. Studies have demonstrated that the use of prebiotics and probiotics can lead to improvements in mood and a reduction in symptom severity for individuals struggling with anxiety or depression. These effects are believed to be mediated through various mechanisms, including the attenuation of inflammatory responses and the modulation of serotonin levels [27]. Therefore, incorporating probiotics into the treatment regimen of elite athletes, alongside psychological and psychiatric interventions, may prove beneficial in managing and preventing mental health disorders. By maintaining a healthy microbiota-gut-brain axis, athletes can potentially reduce the risk of developing mental health issues and improve their overall well-being and performance.

Anti-inflammatory properties. Athletes who engage in high levels of physical activity often experience an increase in circulating reactive oxygen species (ROS). Even just one session of intense exercise can lead to a significant rise in ROS levels, resulting in elevated inflammatory markers [29]. This oxidative stress occurs when there is an imbalance between the body's antioxidant system and the production of ROS and RNS (reactive nitrogen species). The disruption of redox homeostasis can have various negative effects on the body, including impairing important signaling pathways within and between cells. Additionally, the overproduction of ROS and RNS can cause damage to molecules in the body. These oxidative stress markers are produced in muscle fibers at rest, with levels increasing during muscle contractions [30]. While inflammation is a key component of muscular adaptation to exercise, athletes undergoing strenuous training or competition may benefit from reducing inflammation to improve performance in subsequent high-intensity bouts. A systematic review and meta-analysis by Nazari et al. on the effects of probiotic consumption on inflammatory markers in athletes found that probiotics may help reduce levels of IFN-γ, IL-6, and TNF-α. [29].

Performance enhancement. Microbiomes of athletes have been found to have unique microbial compositions characterized by higher levels of *Veillonellaceae, Bacteroides, Prevotella, Methanobrevibacter,* or *Akkermansia* [31,32]. In a study by Scheiman et al., the

relationship between *Veillonella* and exercise performance was investigated. The researchers observed a significant increase in *Veillonella* levels in marathon runners post-race. Specifically, *Veillonella atypica* was isolated from stool samples, and experiments using labeled lactate in mice demonstrated that lactate from the bloodstream can pass through the gut barrier. Additionally, propionate administration was shown to replicate the exercise performance benefits associated with *V. atypica*. These findings suggest that *V. atypica* enhances athletic performance by converting lactate into propionate, underscoring the role of microbiome-encoded enzymatic processes in improving physical endurance. Since lactate is a byproduct of intense exercise, *Veillonella* can metabolize it into beneficial byproducts such as propionate, which may help support endurance and facilitate recovery during prolonged physical exertion. Using a combination of metagenomic and metabolomic analyses, the authors linked the presence of *Veillonella* to improved performance, particularly in endurance sports [33]. Similarly, a study by Shing et al. investigated the effects of probiotic supplementation on athletic performance. Runners were randomly assigned to receive either a daily probiotic capsule (containing 45 billion CFU of *Lactobacillus*, *Bifidobacterium*, and *Streptococcus* strains) or a placebo, with a washout period in between (double-blind, cross-over design). After each treatment, the participants exercised to the point of fatigue at 80% of their ventilatory threshold, under conditions of 35°C and 40% humidity. The results showed that probiotic supplementation significantly increased the time to fatigue during the run (37:44 ± 2:42 minutes for probiotics versus 33:00 ± 2:27 minutes for placebo; $P = 0.03$, $d = 0.54$) [34]. These studies collectively highlight the potential of microbiome-based interventions to improve athletic performance, particularly in endurance sports. However, the authors suggest that further research is needed to fully understand the mechanisms behind this performance enhancement. Probiotic supplementation has been shown to enhance physical performance by promoting muscle protein turnover, improving muscle strength and endurance, reducing fatigue indicators, and increasing aerobic capacity. Specific strains, such as *Lactobacillus* and *Bifidobacterium*, have been found to alleviate exercise-induced fatigue [35]. Probiotics can be used either as multi-strain formulations or as single-strain products, depending on the intended effect. A study by Mazur-Kurach et al. demonstrated that multi-strain probiotic supplementation led to significant improvements in aerobic capacity. This was evidenced by increased maximal oxygen uptake, prolonged exercise duration to failure, higher ergometer load, lower heart rates, and reduced discomfort during exercise testing, all of which confirmed the positive impact of probiotics on cyclists' exercise performance [36]. However,

other studies suggest that the efficacy of probiotics should not be judged solely on the number of strains included in the product. Instead, the selection of probiotics should be guided by evidence from well-conducted trials. In many cases, multi-strain formulations have not been found to offer significant advantages over single-strain probiotics in improving performance [37]. Thus, more research is needed to determine the optimal probiotic strain or combination for maximizing athletic benefits.

TABLE 1. A brief overview of several probiotics with health-promoting potential and performance benefits.

Probiotic strain	**Related health and sport benefits**
Akkermansia muciniphila	Its activity has been related to the thickness of the intestinal wall, resulting in reduced food absorption [38].
Streptococcus thermophilus	This species promotes immunestimulation through cytokine release, enhancing the body's immune response and an increase in VO2max and aerobic power [10,18,35].
Lactobacillus rhamnosus	*Lactobacillus rhamnosus* is primarily localized in the colon and aids in immunestimulation through cytokine release. Its beneficial actions include defense against pathogens such as Candida spp., improved aerobic capacity, reduced gastrointestinal permeability, and a healthier inflammatory response [18,35,38].
Lactobacillus reuteri	Consumption of *Lactobacillus reuteri* has been shown to increase gut microbiota diversity and promote immunestimulation, boosting the body's immunity [18].
Lactobacillus plantarum	*Lactobacillus plantarum* contributes to immunestimulation by increasing IgA-producing cells, improves iron bioavailability, enhances aerobic capacity, and benefits the upper respiratory tract [18, 35].
Lactobacillus lactis	*Lactobacillus lactis* promotes immunestimulation by increasing IgA-producing cells, strengthening the body's immune response [10, 35]

Lactobacillus paracasei	*Lactobacillus paracasei* has been associated with reducing fatigue indicators, improving physical performance, and modulating the inflammatory response in the body [18, 30].
Lactobacillus casei	*Lactobacillus casei* has been shown to enhance aerobic capacity and positively impact psychological state. Studies have indicated that probiotic supplementation with *Lactobacillus casei* can reduce stress and anxiety, while increasing aerobic capacity [35].
Lactobacillus acidophilus	*Lactobacillus acidophilus* influences carbohydrate bioavailability and metabolism, assisting in the efficient processing of carbohydrates in the body [35].
Bifidobacterium longum	*Bifidobacterium longum* has been linked to improved physical performance and protective functions in the gastrointestinal tract, enabling individuals to enhance their athletic abilities and stamina [10, 18, 30, 38, 39].
Bifidobacterium subtilis	Studies have shown that *Bifidobacterium subtilis* can improve physical performance by the attenuation of inflammation and immune stimulation, aiding athletes in achieving optimal results during exercise [18, 40].
Bifidobacterium breve	Consuming *Bifidobacterium breve* has been shown to boost immunestimulation through cytokine release, improve intestinal barrier function, and enhance lung function, contributing to overall health and well-being [10, 18].

Conclusions

Probiotics have been shown to provide many health benefits within the microbiota-gut-brain axis, making them a new focus of research in the field of athletics. Studies have indicated that many athletes face a variety of health challenges, including gastrointestinal disturbances, weakened immune function, mental health issues, and increased inflammation. These conditions can negatively affect performance and recovery, making them critical areas of

concern for athletes. Consuming specific probiotic strains may support immune function and help reduce the number of sick days athletes experience during training or competition. Furthermore, the growing competition among endurance athletes has prompted an increase in research on probiotics aimed at enhancing endurance and performance. Certain strains of probiotics, such as *Lactobacillus* and *Bifidobacterium*, have demonstrated promising effects. Further studies should also be conducted to examine the microbiota and its changes in athletes. Discoveries, such as the potential impact of elevated levels of *Veillonella* species in athletes, could enhance our understanding of the mechanisms that contribute to improved endurance and performance. It is recommended that athletes use clinically studied probiotics (products) with proven benefits. Given the promising effects of probiotics, it is recommended that athletes use clinically studied probiotic products with proven benefits, ideally those that have undergone rigorous testing for their efficacy and safety. While early research is encouraging, more studies are necessary to fully elucidate the underlying mechanisms through which probiotics affect athletic performance. Additionally, future research should aim to identify the optimal strains and dosages for athletes, ensuring that probiotic supplementation can be effectively tailored to meet the specific needs of different sports disciplines and athletic populations.

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Conceptualization: MZ, AN

Methodology: MZA, GB

Software: GB, AN

Check: PN, WP, MZA

Formal analysis: WP, MZ

Investigation: AN, MZ, GB

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