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Review Article

The Effect of Probiotics on Sport Performance of Athletes: A Review on Best Probiotics

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ABSTRACT

Probiotics have gained a lot of attention in sport nutrition and even athletes by their utilization have tried to improve their performance. The beneficial microorganisms of probiotics can play an important role in gut health, and subsequently has a direct impact on general health and nutrient absorption. The best probiotics for athletes are those that improve athletic performance and recovery. Probiotics supplementation has been effective in reducing muscle pain and fatigue, improving adaptation to exercise, and the function of immune system. This review determined the best probiotic strains for athletes, their benefits, proper dosage, and how to use them in a diet. Also, the latest researches on probiotics and sport performance were discussed.

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Introduction

Probiotics are the live and useful microorganisms if consumed in sufficient quantities that can improve general health in their host (1). These beneficial bacteria and yeasts play a very important role in maintaining the health of the intestines and digestive system and are a new debate in the science of sports nutrition (2). The most common probiotic strains belong to the *Lactobacillus* and *Bifidobacterium* genera, although other bacteria and yeasts may also be used in food products containing probiotics (3).

Types of Probiotics

There are different types of probiotics, each of which has specific benefits for athletes including (i) *Lactobacillus* species: *L. acidophilus, L. rhamnosus, L. casei, and L. plantarum;* (ii) *Bifidobacterium* species: *B. longum, B. breve, and B. infantis*; (iii) *Saccharomyces boulardii* (a beneficial yeast) and (iv) *Escherichia coli* (4, 5).

Function and Role of Probiotics

Probiotics function through several mechanisms to support athletic performance and overall health. The functions of probiotics in the body were demonstrated as (i) colonization and normalization of gut microbiota as probiotics can help establish a balanced and diverse gut microbiome, which is crucial for optimal digestion and nutrient absorption (6). (ii) Production of beneficial compounds as some probiotics produce short-chain fatty acids (SCFA) and other metabolites that can support gut health and may have systemic effects (7). (iii) Modulation of the immune system as probiotics can influence the immune response and potentially reduce the inflammation (8). (iv) Interaction with the gut-

brain axis; while certain probiotics may affect mood and cognitive function, which can be beneficial for athletes dealing with mental fatigue (9). (v) Enhancement of nutrient absorption as probiotics can improve the absorption of essential nutrients and potentially aid the muscle recovery (10).

For athletes, these mechanisms can lead to reduced muscle soreness, fatigue and body fat percentage, increased muscle mass, and improved exercise adaptation (11). However, the important thing is that the effects of probiotics depend on the specific strain, dosage and time of their use (12).

Potential Benefits of Probiotics for Athletes: Recovery Efficiency

Athletes face unique challenges that can affect their gut microbiome, and probiotics offer multiple benefits to address these issues. Another significant benefit of probiotics for athletes is their potential to enhance recovery after intense exercise. Intense physical activity can lead to muscle damage, inflammation, and oxidative stress, all of which can impair an athlete's performance (13). Probiotic supplementation has been shown to have anti-inflammatory effects, which can help reduce muscle soreness and improve recovery times. Some studies have reported decreased levels of inflammatory markers such as Tumor necrosis factor alpha (TNF-α) and interleukin-6 (IL-6) in athletes taking probiotics. This reduction of inflammation helps in faster recovery and improvement of sports performance (14, 15). Moreover, probiotics may have a positive impact on muscle protein turnover and glycogen storage (16, 17). By increasing the absorption of amino acids and improving the storage of glycogen in the liver and skeletal muscles, probiotics can support muscle recovery and energy replenishment after intense exercise (18).

Improved Immune Function

One of the benefits of probiotics is the positive effect on the immune system. An intense physical activity can lead to temporary suppression of the immune system and make athletes more susceptible to upper respiratory tract infections (URTIs) (19, 20). Probiotics have been effective in reducing the incidence of URTIs in athletes (21, 22). Additionally, probiotics have been found to increase salivary immunoglobulin A (IgA) levels, which has a positive influence on mucosal immunity. This increased mucosal immunity can help reduce the risk of respiratory infections and allow athletes to maintain their competitive edge. (23).

Reduced GI Distress

Gastrointestinal (GI) issues are common among athletes, particularly those engaged in endurance sports (24). These problems can range from mild discomfort to severe symptoms that can affect performance. Probiotics can reduce GI discomfort (25). Researches have indicated that probiotic supplementation can reduce the frequency and severity of GI symptoms in athletes during training and competition. By improving gut barrier function and reducing intestinal permeability, probiotics may help prevent the translocation of toxins from the gut into the bloodstream, which can contribute to GI discomfort (26, 27). Furthermore, probiotics can enhance the production of SCFAs in the gut, which have beneficial effects on gut health and may contribute to improved GI distress during exercise. It can be beneficial for endurance athletes who experience GI problems during long periods of physical activity (28, 29) (Table 1).

Best Probiotic Strains for Athletes

Some of the most effective probiotic strains utilized by athletes are listed below:

Lactobacillus

Lactobacillus strains have been discussed more than other probiotic strains due to their significant effects in improving athletic performance.

L. plantarum

L. plantarum is the most effective type on sport performance, recovery, improvement of general health and immune system activity, as well as prevention of the symptoms digestive diseases (40).

L. plantarum PS126

One notable subspecies is *L. plantarum* PS128, which has shown promising results in sports performance (41). In a 4-week study involving 10 males (21.6±1.3 years), supplemented with *L. plantarum* PS128, it was shown that supplementation was associated with an improvement in endurance running performance that can be through microbiota modulation and related metabolites. This suggests that this strain may be beneficial to enhance endurance performance (39).

L. plantarum BP06

A research showed that supplementing this subspecies of lactobacillus in 11 male soccer players along with the Bruce test could increase the aerobic capacity and the time to reach fatigue (42).

L. plantarum TWK10

L. plantarum TWK10 supplementation for 6 weeks with a dose of 1×10^{11} CFU in mice caused

a decrease in inflammatory factors and increased energy and the ability to make glycogen in their muscles (16). Also, 6 weeks of *L. plantarum* TWK10 supplementation could increase the muscle mass and endurance in swimming rats (43).

Table 1: A summary of studies on the effect of probiotic supplementation on sport performance in athletes.

Subject group	Sex and age (M ± SD)	Supplementation	Treatment duration	Exercise	Sports Benefits	Reference
Road cyclists	11 elite males cyclists aged 19–40 y	4.3×10^9 CFU *Lactobacillus helve- ticus Lafti* L10, 4.3×10^9 CFU *Bifidobacteriumanimalis* ssp. *lactis Lafti* B94, 3.9×10^9 CFU *Enterococcus faecium* R0026, 2.1 × 109 CFU *Bifidobacterium longum* R0175 (14.3 %) and $\geq 0.4 \times 10^9$ CFU *Bacillus subtilis* R0179	90 d	Cycling at 85% of maximal power	No effect on POmax, VO2 max and Time to fatigue No effect on IL-6 and TNF-α Significantly lower incidence of GI symptoms, fewer incidences of nausea & vomiting	(30)
Long-Distance Runners	70 males and females 20–60 years	*obacterium lactis* W52, *Lactobacillus brevis* W63, *Lactobacillus casei* W56, *Lactococcus lactis* W19, *Lactococcus lactis* W58, *Lactobacillus acidophilus* W37, *Bifidobacterium bifidum* W23 *and Lactobacillus salivarius* W24 in a dose of 2.5×10^9 CFU/g (1 capsule)	12 weeks	Bruce protocol treadmill	significant increase in lean body mass in men, insignificant decrease in the content of total and visceral adipose tissue in women , No significant difference was observed	(31)
Marathonists	14 males 35.96 ± 5.81	*Bifidobacterium-animalis-subsp.-Lactis* (10×10^9) and *Lactobacillus-Acidophilus* (10×10^9)	30 days	Not reported	Both chronic and acute exercise modulated a different T lymphocyte population (CD3 + CD4 − CD8 − T-cells), increasing pre-race, decreasing post and returning to rest values at the recovery.	(32)
Swimmers	8 Females	*B. longum* 35624 daily dosage of 1×10^{10} CFU	6 weeks	Intensified Exercise Training Phase	higher sport recovery during the final two weeks of the offseason training program	(9)
Elite athletes	39 males and females 23.5 ± 2.7 years	2×10^{10} CFU of *Lactobacillus helveticus Lafti*® L10 daily	98 days	Graded cardiopulmonary test (treadmill)	No significant difference was observed	(33)
Badminton players	30 males 18–30 years	3×10^{10} CFU of *Lactobacillus casei* daily (commercial probiotic drink) mixed with commercial orange juice (in total 200 mL)	42 days	-20 m multi-stage shuttle run	Significantly increase VO2max (mL/kg/min)	(34)

Subject group	Sex and age (M ± SD)	Supplementation	Treatment duration	Exercise	Sports Benefits	Reference
Marathonists	7 males (39.92±3.47) years	f 1 billion CFU *Lactobacillus acidophilus*-LB-G80, 1 billion CFU *Lactobacillus paracasei*-LPc-G110, 1 billion CFU *Lactococcus subp. lactis*-LLL-G25, 1 billion CFU *Bifidobacterium animalis subp. lactis*-*BL*-G101, and 1 billion CFU *Bifidobacterium bifidum*-BB-G90 5×10^9 CFU 2.0 g/day	30 days	Cardiovascular & VO2 peak tes	Probiotic supplementation can effectively reduce the symptoms of minor infections in URTI of marathon athletes while maintaining the immune response.	(35)
Physically active people	105 20-40 years old	2.0×10^{10} CFU/day *Lactobacillus paracasei* PS23	6 weeks	Not reported	prevented loss of strength and exercise performance after muscle damage, and improved inflammatory markers	(36)
Rugby player	19 males	6.0×10^{10} CFU/day Ultrabiotic 60 and 250 mg *SBFloractiv*™ *L. rhamnosus, L. casei, L. acidophilus, L. plantarum, L. fermentum, B. lactis, B. bifidum, S. thermophilus, Saccharomyces boulardi*	17 weeks		Improving sleep quality and reducing muscle pain	(37)
Recreational athletes	51 males recreational athletes	Capsules containing heat killed *Lactococcus lactis* JCM 5805 1 x 10^{11} CFU/d	13 days	Consecutive high intensity exercise	Reduction of fatigue and incidence of URTIs	(38)
Triathletes	10 males (21.6 ± 1.3) yrs	*L. plantarum* 128 supplement group (LG, 3×10^{10} (CFU)/ day)	4 weeks	Endurance exercise	Improvement of endurance running performance through modulation of microbiota and related metabolites, but not in maximal oxygen uptake.	(39)

CFU: Colony-forming units, IL: Interleukin, TNF-α: Tumor necrosis factor-alpha, URTIs: Urinary tract infections.

L. plantarum 299V

Tweleve weeks of supplementation of this subspecies of probiotic in 53 female athletes who had iron deficiency could cause a better bioavailability of iron, increase plasma iron level and reduced incidence of URTIs; but did not affect aerobic capacity (44).

L. plantarum PL02

L. plantarum PL02 is a strain of probiotics that has a human origin. It was shown that 4 weeks of supplementation of this species could significantly increase the muscle mass and strength, endurance performance, and liver glycogen storage. Furthermore, it could significantly decrease lactate,

blood urea nitrogen (BUN), ammonia, and creatine kinase (CK) levels after exercise (45).

L. salivarius

L. salivarius strain is a type of probiotic that has anti-infection properties inside the body or has therapeutic properties for colitis (46).

L. salivarius W24

A research revealed that supplementation of this subspecies increased muscle mass in Runners athletes and improved their breathing (31). Also, 3 months of supplementation of this subspecies along with some other probiotic species in 66 males of 20-60 years old long-distance runners could reduce the constipation and GI symptoms (47).

L.s salivarius UCC118

This subspecies helps to prevent digestive problems, including constipation and diarrhea, especially in endurance athletes by improving the integrity of the mucous membrane along the digestive tract (48).

L. casei and L. paracasei

Several researches illustrated that supplementation of these subspecies reduced muscle oxidative stress and reduced the symptoms of URTI in athletes (49-51). Also, 42 days of *Lactobacillus casei* supplementation in 30 male badminton players aged 18-30 years increased VO2max among them (12). Furthermore, in the research conducted by Jäger *et al.*, it was found that *L. paracasei* supplementation could increase the absorption of essential and branched chain amino acids in male athletes (41).

L. fermentum

11 weeks of supplementation with a dose of 1×10^9 CFU of this species was able to reduce URTI symptoms in male competitive cyclists. *L. fermentum* subspecies were *L. fermentum* (PCC) and *L. fermentum* VRI-003 (52).

Bifidobacterium

Bifidobacterium spp. strains have also shown promise results in supporting sport performance.

B. longum OLP-01 and B. breve

These species has been proven to effectively increase the proportion of beneficial strains in the gut microbiota in animal and human experiments, as well as improving the exercise performance and reducing the exercise-induced fatigue (45). *B. breve* also plays an important role in modulating the immune system and can increase running time to exhaustion in 10 male runners.

B. lactis Bl-04 and B. lactis BI-07

B. lactis Bl-04 and *B. lactis* BI-07 have been shown to have a positive effect on immune markers. This is especially important for athletes, who have intense or prolonged trainings and their immune system is compromised, making them susceptible to URTIs (21).

S. boulardii

S. boulardii is helpful in improving symptoms of diarrhea, which can be beneficial for ultra-endurance athletes who often experience digestive upsets during long training sessions (53, 54).

Dosage and Timing of Probiotic Supplementation

When it comes to the effectiveness of probiotic supplementation in athletes, the right dose and timing are very important to maximize the benefits. The effectiveness of probiotics is dependent on various factors, including the number of bacteria consumed and the specific strains used.

Recommended CFU Counts

Probiotic dosage is typically measured in CFU, which estimates the number of live microbes capable of forming colonies. While there is no one same all approach, it was shown that a daily dose of 10-20 billion CFU is generally sufficient for maintaining immune and digestive health in athletes (9). However, the optimal dosage can vary depending on individual needs and specific health goals. Some studies have used higher doses, ranging from 30 billion to 100 billion CFU per day, with positive results. For example, in one study, taking multi-strain probiotics at 30 billion CFU daily for 12 weeks before a race could help reduce gastrointestinal symptoms in athletes training for their first long-distance triathlon (55).

When to Take Probiotics

The timing of probiotic supplementation can play an important role in its effectiveness for the athletes. Here are some key considerations including (i) Consistency to be a key to maintain a stable probiotic population in the gut. It is the best to take the supplement at the same time each day. Many athletes find it convenient to take their probiotic with breakfast (33, 56, 57). (ii) With or without food; while some probiotics can be taken on an empty stomach. Taking them with food may help protect the bacteria when they pass through the digestive system. This can potentially increase the number of live bacteria that reach the intestines (58). (iii). Antibiotic considerations if someone is taking antibiotics: It

is important to separate the timing between your antibiotic regimen and your probiotics. Wait at least two hours after taking antibiotics before consuming your probiotic supplement to avoid countering the antibiotic's effects (39).

(iv) Before sleeping for athletes looking to increase their performance during competition; it is recommended to take probiotic supplements before sleep. This gives beneficial bacteria time to establish themselves in the gut during a night's rest, and thus can cause beneficial adaptations in exercise (18, 39). (v) Post-workout recovery: Some athletes find it beneficial to take probiotics as part of their post-workout recovery routine, as certain strains may help with muscle recovery and reducing inflammation (18, 39). Therefore, the effects of probiotics vary depending on the specific strain, dose, time of administration, type of exercise and diet. It is recommended to consult with a dietitian to determine the best probiotic supplementation strategy.

Potential Risks and Side Effects

While probiotics have important benefits and safe for athletes, they may also have some side effects. Understanding these issues will help athletes to use probiotic supplements properly. The most common side effects include bloating, gastrointestinal symptoms such as constipation and diarrhea (59, 60). These side effects are usually temporary and after a few days to a few weeks. the symptoms decrease and the body gets used to it. If symptoms worsened, it is recommended to stop taking probiotics and consult a dietitian. Among the rare side effects, Some *Lactobacillus*-based probiotics can cause infection of the inner lining of the heart cavities and heart valves (60). In many cases, air, surfaces, or hands that have been in contact with probiotics are triggered by air, characters, or hands (60).

Provision of Probiotics in the Diet of Athletes

There are two primary ways to introduce these beneficial microorganisms into your system including through food sources and via supplement options.

Food Sources

Probiotic-rich foods offer a natural way to support GI health, athletic performance, and nutrient absorption (61). In addition to beneficial bacteria, these foods also provide essential micronutrients, plant compounds, and fibers that act as prebiotics to feed probiotics in the gut (62). Yogurt is one of the sources of probiotics for athletes.When choosing yogurt, look for those labeled as containing live or active bacteria to ensure you're getting beneficial probiotic strains (48). Kefir is another powerful probiotic source. It contains several key strains of beneficial bacteria and yeast, making it stronger option than yogurt. Kefir can be used as a base for protein shakes too (63). For athletes who are vegan or lactose intolerant, fermented vegetables such as kimchi and sauerkraut are good alternatives. These foods are also source of vitamins and minerals (64).

Supplement Options

While probiotic-rich foods are beneficial, probiotic supplements offer special benefits to athletes looking to improve performance. Supplements allow more precise control over strains and dosage of probiotics. Regular consumption of probiotic sources is necessary to maintain a stable bacterial population in the gut and reap the potential benefits for athletic performance and recovery.

Conclusion

The discovery of probiotic organisms for athletes has highlighted their potential to improve athletic performance and their general health. These beneficial microorganisms affect the health of the digestive system, the function of the immune system and recovery after exercise, and in the new science; they have become a valuable supplement in the field of sports nutrition. By referring to a nutritionist and choosing the right strains and doses, athletes can benefit from the usefulness of probiotics in sports. So the optimal use of probiotics can help athletes achieve new records and goals in their chosen disciplines, although we still need more researches in this field.

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Authors' Contribution

All authors read and approved the manuscript. Investigation, supervision, review and editing was performed by Daryanoosh F, Review by Rabiee MR and conceptualization, data collection, manuscript drafting, review and editing and other tasks was carried out by Izadi MA.

Conflict of Interest

None to declare.

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