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The Role of Gut Microbiota in Shaping Physical Performance and Immunity in Active Individuals: A Review of Current Evidence

Corresponding Author: Oliwia Mirkowska [OM]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0002-3949-4485
Email: oliwia.mirkowska@gmail.com

Zuzanna Leciej [ZL]
Pomorski Uniwersytet Medyczny w Szczecinie, Szczecin, Poland
ORCID: https://orcid.org/0009-0005-4234-1772
Email: leciejzuzanna@gmail.com

Michał Lubkowski [ML]
Pomorski Uniwersytet Medyczny w Szczecinie, Szczecin, Poland
ORCID: https://orcid.org/0009-0007-4600-8920
Email: michal.lubkowski@pum.edu.pl

Gabriela Afrykańska [GA]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0000-0290-0297
Email: gabrielaafryka@gmail.com

Gabriela Fryszer [GF]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0008-4189-7244
Email: gabrysia.fryszer@icloud.com

Krzysztof Orzeł [KO]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0004-4863-7059
Emai: korzel9904@gmail.com

Bernard Pomykała [BP]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0004-5343-7457
Email: ben_pomykala@icloud.com

Hubert Skwarna [HS]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0007-6090-4393
Email: hubskw112@gmail.com

Kinga Krzysztofik [KK]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0004-0184-8940
Emai: kingakrzysztofik7@gmail.com

Aleksandra Banasik [AB]
Medical University of Warsaw, Warsaw, Poland
ORCID: https://orcid.org/0009-0004-2414-7581
Email: ola.banasik18@gmail.com

Abstract

Background: Growing evidence highlights the gut-muscle axis as a prominent area of research in sports science, illustrating a connection between the gastrointestinal tract and skeletal muscles. While individual factors such as diet and age influence the microbiome, physical exercise is increasingly recognized as a profound modulator of gut microbiotas' composition.

Purpose: The aim of this review is to evaluate recent scientific evidence on how the gut microbiota influences physiological performance, metabolic adaptations, and immune system function in athletes and physically active individuals.

Findings: Recent evidence demonstrates that regular physical activity significantly enhances the alpha-diversity and abundance of beneficial microbial species. Studies show that athletes exhibit higher alpha-diversity and lower systemic inflammatory markers compared to sedentary controls. Distinct taxa, such as *Akkermansia muciniphila*, contribute heavily to mucosal barrier integrity and metabolic optimization. Furthermore, specific microbial groups actively augment performance, for example, *Veillonella atypica* metabolizes exercise-induced lactate into propionate—a short-chain fatty acid (SCFA) utilized by skeletal muscles to enhance aerobic endurance. Practically, institutional consensus from the International Society of Sports Nutrition (ISSN) indicates that dose-dependent probiotic supplementation supports gut barrier function, enhances nutrient absorption, and reduces the risk of upper respiratory tract infections.

Conclusion: The gut microbiota exerts a profound influence on athletic capacity and systemic health. Modulating this ecosystem through targeted, evidence-based probiotic supplementation opens compelling new horizons for optimizing recovery, immunity, and athletic performance.

Keywords: Gut-muscle axis, Alpha-diversity, *Veillonella atypica*, *Akkermansia muciniphila*, Probiotics, Short-chain fatty acids (SCFAs), Athletic performance

Introduction

To fully understand the adaptations observed in athletic cohorts, it is essential first to establish the baseline physiological responsibilities of a healthy microbiome.

The gut microbiota, often referred to as the gut flora, consists of microorganisms such as bacteria and fungi that colonize the human digestive tract. The normal human gut microbiota is comprised of two major phyla, namely Bacteroidetes and Firmicutes. Numerous individual factors can affect the composition of the gut microbiota, including antibiotic use, age, diet and physical exercise. [1]

This complex microbial community exerts specific functions. In terms of host nutrient metabolism, by metabolizing dietary fiber and other particles that humans are unable to digest, these microorganisms assist in the absorbtion of nutritional compounds. Furthermore the microbiota helps maintain the integrity of the gut mucosal barrier. This defensive barrier relies heavily on a thick, slippery top coat of mucus that physically traps pathogens. Specialized bacteria such as *Akkermansia muciniphil*a, continuously graze on the outer edge of this mucus layer. triggers a signaling cascade to the host's goblet cells to secrete more mucin.[2] This cycle of degradation and renewal keeps the inner mucus layer thick and robust. The presence of the two tiered mucus layer is also one of the simplest mechanisms of antimicrobial protection as the inner coat prevents luminal microbes from direct contact with epithelial lining. Beyond barrier maintenance, the gut microbiome also plays an enormous role in xenobiotic and drug metabolism, as well as immunomodulation—such as shaping a normal GALT.[3]

Consequently, the role of gut microbiome has recently been linked by scientists with physical performance. Due to the microbiota's ability to modulate the immune system, assist with energy uptake and its indirect effect on human performance and recovery known as "gut-muscle axis" it has become a prominent research topic for both scientists and athletes[4].

High-intensity physical training induces acute metabolic and oxidative stress, often triggering transient gastrointestinal distress and increased epithelial permeability, a phenomenon frequently referred to as "leaky gut". This can disrupt immune function, rendering athletes more susceptible to systemic fatigue and upper respiratory tract infections. By acting as a biological

[1] Jandhyala et al., „Role of the normal gut microbiota".
[2] Derrien et al., „Akkermansia Muciniphila and Its Role in Regulating Host Functions".
[3] Jandhyala et al., „Role of the normal gut microbiota".
[4] Mohr et al., „The Athletic Gut Microbiota".

shield, a well-balanced intestinal microbiome not only suppresses exercise-induced inflammation but also optimizes cellular energy production through metabolic byproducts.

Therefore, the aim of this article is to review the recent literature on how the bacteria within the gut microbiome affect performance and immunity in active individuals.

Methodology

For the purpose of writing this review we searched PubMed, Clinical Nutrition Journal, National Libraryof Medicine to find articles published after 2013. We use phrases and keywords such as "gut microbiota", "intestinal microbiome", "athletes", "exercise", "physical activity", "sedentary lifestyle", "gut-muscle axis", and "gut-brain axis". Specific bacterial taxa, such as "*Veillonella atypica*"and "*Akkermansia muciniphila*". Studies were screened and selected based on criteria that required articles to be: published in English in peer-reviewed scientific journals and focused directly on the intestinal microbiota or its influence on physical exercise.

The Impact of Physical Activity on Gut Diversity

Numerous studies have demonstrated that physical activity not only increases the amount of bacteria within the gut microbiome but is also a key factor in enhancing the alpha-diversity of these microorganisms[5], which correlates with improved gut immune function.

In one such study, stool and urine samples from professional male rugby players were analyzed alongside plasma creatine kinase levels (a marker of extreme exercise). The findings revealed that despite elevated creatine kinase levels, the rugby players exhibited a lower inflammatory status than the controls. Furthermore, the alpha-diversity of the athletes' microbiota was significantly higher than that of the control group. Specifically, 22 phyla, 68 families and 113 genera were detected in rugby players' fecal samples, as opposed to 11 phyla, 33 families and 65 genera detected in the low-BMI controls, and 9 phyla, 33 families, 61 genera in the high-BMI controls [6]

In another study, the female gut microbiota was compared among patients with anorexia nervosa, obese, overweight and normal-weight individuals, as well as athletes. The researchers demonstrated that alpha-diversity was significantly lower in both the anorexia nervosa patients

[5] Clarke et al., „Exercise and Associated Dietary Extremes Impact on Gut Microbial Diversity".
[6] Clarke et al., „Exercise and Associated Dietary Extremes Impact on Gut Microbial Diversity".

and obese participants compared to the other groups, whereas athletes exhibited the highest alpha-diversity.[7]

Furthermore, evidence suggests that not only the diversity but also the specific composition of the gut microbiota plays a crucial role. In particular, the bacterium *Akkermansia muciniphila* has caught researchers' attention due to its significant role in maintaining gut mucosal barrier integrity. In a study by Everard et al., the authors concluded that the presence of *A. muciniphila* can thicken the inner mucus layer of the large intestine by up to 46%. They also correlated its presence with an improved metabolic profile, reduced body weight and decreased intestinal inflammation in diet-induced obese mice[8].

Additionally, studies such as that by Clarke et al. demonstrate that physically active individuals possess a higher abundance of *A.Muciniphila* compared to sedentary individuals. This suggests that regular exercise is a beneficial, quality-shaping factor for the gut microbiome.

Table 1

Bacteria	Active individuals	Sedentary controls
Veillonella atypica	High abundance (elevated after physical activity)	Low abundance
SCFA-producing bacteria	High abundance and diversity	Reduced population
Akkermansia muciniphila	High abundance	Low abundance
Lactobacillus and Bifidobacterium	High abundance and stability	Low abundance, more often dysbiosis
Bacteroides	Optimized profile (high Bacteroidetes/Firmicutes ratio)	Imbalanced profile, more often dysbiosis

To visualize these physiological dynamics, Table 1 summarizes the distinct compositional differences in the gut microbiota of physically active individuals compared to sedentary controls.

[7] Mörkl et al., „Gut Microbiota and Body Composition in Anorexia Nervosa Inpatients in Comparison to Athletes, Overweight, Obese, and Normal Weight Controls".

[8] Everard et al., „Cross-talk between Akkermansia muciniphila and intestinal epithelium controls diet-induced obesity".

Gut Microbiota and Physical Performance

Gut microbiota modulates human physical capacity through multiple mechanisms of the gut-muscle axis.

Bacteria present in the gut ferment dietary fiber, a process that produces short-chain fatty acids (SCFAs) such as butyrate, propionate, and acetate.

Once absorbed, these SCFAs are transported to skeletal muscles, where they serve as an alternative energy source. Furthermore, butyrate acts as a signaling molecule that stimulates the biogenesis of new mitochondria in muscle tissues, thereby directly enhancing aerobic capacity.[9] Beyond acting as a direct substrate for ATP synthesis, SCFAs play a pivotal role in modulating skeletal muscle glycogen metabolism and vascular compliance.[10] Specifically, acetate and propionate serve as vital precursors for hepatic gluconeogenesis and lipogenesis, thereby stabilizing blood glucose levels during prolonged cardiovascular exertion.[11] Additionally, SCFAs exhibit potent systemic vasodilatory effects by interacting with G-protein coupled receptors (GPCRs) on vascular endothelial cells, effectively improving microcirculation and oxygen delivery to working muscle fibers.[12]

The presence and role of the genus *Veillonella* represented a major discovery in sports medicine.

During exercise, lactic acid accumulates in the muscles and diffuses into the systemic circulation, eventually reaching the intestinal lumen, where *Veillonella atypica* utilizes this lactate as its primary carbon source[13]

In a study by Scheiman et al., which analyzed runners from the 2015 Boston Marathon alongside sedentary controls, the authors concluded that *V. atypica* in the athletes' guts, improves treadmill runtime. This performance enhancement is attributed to the bacterium's metabolic conversion of exercise-induced lactate into propionate [14] - an SCFA that is subsequently used by muscles, improving endurance.

[9] Mohr et al., „The Athletic Gut Microbiota".
[10] Canfora et al., „Short-chain fatty acids in control of body weight and insulin sensitivity".
[11] Canfora et al., „Short-chain fatty acids in control of body weight and insulin sensitivity".
[12] Ticinesi et al., „Aging Gut Microbiota at the Cross-Road between Nutrition, Physical Frailty, and Sarcopenia".
[13] Scheiman et al., „Meta'omic analysis of elite athletes identifies a performance-enhancing microbe that functions via lactate metabolism".
[14] Scheiman et al., „Meta'omic analysis of elite athletes identifies a performance-enhancing microbe that functions via lactate metabolism".

The Role of the Microbiome in Immunosurveillance and URTI Prevention

A critical challenge in sports medicine is the transient immune suppression that follows prolonged, high-intensity exertion, a phenomenon often explained by the 'open window' theory.[15] During this post-exercise recovery phase, parameters of the immune systems temporarily decline, leaving athletes highly susceptible to upper respiratory tract infections (URTIs). Research indicates that elite competitors experience a significantly higher incidence of URTIs during periods of intensified training and competition, which can disrupt training schedules and compromise performance.

Approximately 70% of the body's immune cells reside within the gut-associated lymphoid tissue (GALT), which relies on continuous stimulation from a diverse microbial ecosystem to function optimally.[16] The role of the gut microbiota in shaping a functional gut-associated lymphoid tissue (GALT) is fundamental. An absence or disruption of microbial colonization leads to the severely impaired development of Peyer's patches and isolated lymphoid follicles. [17] These specialized anatomical structures serve as the primary induction sites for mucosal immunity.

Furthermore a well-structured microbiome promotes the production of secretory immunoglobulin A (sIgA) and regulates systemic cytokine profiles, thereby reinforcing the first line of defense against airborne pathogens.[18]

This clinical efficacy was clearly demonstrated in a randomized, double-blind, placebo-controlled trial conducted by West et al. on elite athletes. The researchers found that a multiple week course of probiotic supplementation significantly reduced the incidence and duration of URTI episodes, effectively cutting the number of symptomatic days in half compared to the placebo group[19]. Consequently, maintaining gut homeostasis is vital not only for gastrointestinal comfort but as a frontline defense strategy to shield the athlete from opportunistic infections.

[15] Walsh, „Recommendations to Maintain Immune Health in Athletes".
[16] Pyne et al., „Probiotics Supplementation for Athletes – Clinical and Physiological Effects".
[17] Jandhyala et al., „Role of the normal gut microbiota".
[18] Gleeson et al., „The Anti-Inflammatory Effects of Exercise"; Tavares-Silva et al., „Effect of Multi-Strain Probiotic Supplementation on URTI Symptoms and Cytokine Production by Monocytes after a Marathon Race".
[19] West et al., „Probiotic Supplementation for Respiratory and Gastrointestinal Illness Symptoms in Healthy Physically Active Individuals".

The Gut-Brain Axis: Modulating Stress, Anxiety, and Mood in Active Individuals

The communication pathway between the central nervous system and the gastrointestinal tract, known as the gut-brain axis, plays a pivotal role in psychological resilience and cognitive performance under pressure. Elite athletes and highly active individuals are routinely subjected to immense psychophysiological stress, including anxiety and high cortisol levels. Emerging research demonstrates that the gut microbiota directly modulates this axis by synthesizing key neurotransmitters, such as gamma-aminobutyric acid (GABA), serotonin, and dopamine.[20] Specific strains of Lactobacillus and Bifidobacterium—often referred to as psychobiotics[21]—have been shown to attenuate the hypothalamic-pituitary-adrenal (HPA) axis response to acute stress. By lowering systemic cortisol and reducing pro-inflammatory cytokines that affect brain function, a well-balanced microbiome helps mitigate symptoms of anxiety and depressive states[22]

The Gut-Bone-Muscle Axis: Impact on Bone Mineral Density and Joint Recovery

Ohlsson and Sjögren in their research point to how the gut microbiota regulates bone mass by modulating the host's immune system. Key commensal bacteria modulate the proliferation and signaling of specific immune cells, thereby increasing bone resorption and maintaining optimal level skeletal remodeling.[23] In a state of overtraining or caloric restriction, pro-inflammatory cytokines such as TNF-alpha and IL-1 often accelerate bone resorption. Microbes actively suppress these inflammatory cascades, preserving bone structural integrity. [24] Furthermore, production of SCFAs by the gut microbiome lower the pH of the intestines, which enhances absorption of minerals such as calcium and magnesium[25]. Elite athletes, particularly those in high-impact disciplines, endurance running, or weight-category sports, frequently face severe skeletal stress, putting them at elevated risk for stress fractures, osteopenia, and mechanical joint inflammation. Consequently, targeting the gut-bone-muscle axis offers a new therapeutic direction to accelerate musculoskeletal recovery and reduce the incidence of stress injuries in active populations.

[20] Cryan et al., „The Microbiota-Gut-Brain Axis".
[21] Sarkar et al., „Psychobiotics and the Manipulation of Bacteria–Gut–Brain Signals".
[22] Clarke et al., „Exercise and Associated Dietary Extremes Impact on Gut Microbial Diversity".
[23] Ohlsson i Sjögren, „Effects of the Gut Microbiota on Bone Mass".
[24] Tyagi et al., „The Microbial Metabolite Butyrate Stimulates Bone Formation via T Regulatory Cell-Mediated Regulation of WNT10B Expression".
[25] Whisner i Castillo, „Prebiotics, Bone and Mineral Metabolism".

Practical Implications: The International Society of Sports Nutrition Stand on Probiotics

In their study on probiotics and vitamin D3 supplementation on sports performance in martial arts athletes, Przewłócka et al. demonstrated that four weeks of combined supplementation enhanced lactate utilization and beneficially affected anaerobic performance.[26] Specifically, the researchers observed a significant reduction in post-exercise blood lactate concentrations during high-intensity anaerobic testing, suggesting that the body can clear and reuse lactate much faster after exercise.

Furthermore, the inclusion of vitamin D3 alongside probiotics appears to address a frequent nutritional deficiency in indoor sports disciplines, where low vitamin D status often impairs skeletal muscle tissue remodeling and calcium homeostasis. By optimizing the gut-muscle axis simultaneously through structural support (vitamin D3) and metabolic regulation (probiotics), this combined approach helped sustain an optimal level of performance under high physical strain and supported overall recovery.

Translating scientific findings into practical applications, the International Society of Sports Nutrition (ISSN) issued an official position stand regarding probiotic supplementation for active individuals.

The ISSN states that the efficacy of supplementation is dose-dependent, meaning probiotics must be administered in adequate dosages to exert a beneficial influences on health. These benefits include improved gastrointestinal barrier function, enhanced nutrient absorption, boosted immune health and a decreased risk of upper respiratory tract infections[27]

Conclusion

In conclusion, the gut microbiota represents a crucial yet underappreciated component of athletic performance. It plays an essential role in modulating metabolic pathways, facilitating lactate utilization, and strengthening the mucosal barrier. Rather than focusing solely on macronutrient ratios, modern sports nutrition should acknowledge the gut-muscle axis as the system that can affect metabolic efficiency. The data gathered from specialized cohorts, such as elite runners and combat sports athletes, emphasize that targeted microbial support can actively decrease training-induced immunosuppression and improve energy utilization.

[26] Przewłócka et al., „Effects of Probiotics and Vitamin D3 Supplementation on Sports Performance Markers in Male Mixed Martial Arts Athletes".

[27] Jäger et al., „International Society of Sports Nutrition Position Stand".

Consequently, this area of research opens new horizons, with recent literature highlighting probiotic supplementation as a promising avenue for active individuals.

Disclosure

Author's contribution

Conceptualization: O.M and A.B

Methodology: G.A, G.F and K.K

Formal analysis: A.B, K.O and B.P

Resources: Z.L, M.L and H.S

Writing: O.M, K.K and G.A

Review and editing: H.S, G.F and B.P

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The authors deny any conflict of interest

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During the preparation of this work, the authors used Google Gemini for the purpose of improving language and readability, verification of bibliographic styles, and basic data analysis. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the substantive content of the publication

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