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Examining The Relationship Between Gut Microbiota And Sports Performance: A Narrative Review

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Abstract

The microorganisms inhabiting the gastrointestinal tract play a crucial role in human health, influencing nutrient absorption, vitamin synthesis, energy extraction, inflammatory regulation, and the host's immune response. Various factors, such as age, delivery method at birth, antibiotic usage, and dietary choices, are recognized as formative elements shaping the gut microbiota. However, the impact of exercise, including associated factors like sport-specific diet, environmental conditions, and their interactions on the gut microbiota, remains less explored. High-level athletes exhibit distinctive physiology and metabolism, offering valuable insights into gut microbiota research due to their exceptional muscular strength, aerobic capacity, energy expenditure, and heat production. Given the gut microbiota's ability to influence energy utilization, immune modulation, and gastrointestinal health, it likely plays a pivotal role in athlete health, well-being, and sports performance. This understanding is particularly significant for athletes aiming to enhance competition results and expedite recovery during training. Moreover, the research extends beyond athletics, with implications for overall health and wellness in broader communities. Therefore, this narrative review aims to summarize existing knowledge on the gut microbiota in athletes and the factors influencing it, acknowledging the challenges associated with disentangling its effects from lifestyle and dietary habits.

Keywords: Gut Microbiota, exercise, diet, health, energy.

Introduction

The primary aim of this story is to explore the connection between gut microorganisms and physical activity, investigating whether there's enough proof to consider innovative approaches for the recovery and protection of the intestines as a significant factor in overall performance. Joshua Lederberg, an American biologist honored with the Nobel Prize in Medicine in 1958, highlighted how the microorganisms within our bodies collaboratively protect us. These microorganisms, now collectively termed microbiota, consist of various living entities such as eukaryotes, archaea, bacteria, and viruses, making up about 1.3% of our body mass and playing a crucial role in maintaining optimal health. These microorganisms inhabit diverse areas of the body, settling on surfaces like the respiratory system, digestive system walls, urogenital system, among others [1]. The intestinal tract and mouth exhibit greater microbiota diversity, while the skin has less diversity, and there's still no consensus on the number of species in the vagina [2].

Microbiota refers to the collection of microorganisms residing in each environment, establishing a symbiotic relationship with adaptive properties and rapid renewal, creating a significant metabolic unit. The intestinal microbiota specifically comprises around 100 billion bacteria residing in our intestines, responsible for maintaining intestinal mucosa well-being, aiding in digestion, and transforming harmful elements into less toxic substances. In 2014, the term "intestinal flora" was introduced to describe the intestinal microbiota, later changed to "gut microbiota" [3].

Certain bacteria in the gut microbiota attach to cell exteriors and specific receptors known as adhesins. They can adapt to environmental conditions, such as humidity, temperature, or pH, activating defense mechanisms when interacting with harmful viruses. The balance between microbiota, intestinal permeability, and local immunity is crucial for intestinal tract stability. Any non-adaptive changes can have adverse effects, referred to as intestinal dysbiosis, impacting digestion, nutrient absorption, vitamin production, and control of harmful microorganisms [3]. The majority of gut microbiota bacteria reside in the colon, described as a potentially active organ due to extensive microbiota activity and likened to the liver for its high metabolic capacity [5]. The microbiota is dominated by four main groups: Firmicutes, Bacteroidetes, Actinobacteria, and Proteobacteria [6]. While other bacteria in smaller proportions contribute to microbiota function, Firmicutes and Bacteroidetes are notable, making up about 60% and 20%, respectively, of the gut microbiota throughout the intestinal tract. The Proteobacteria phylum covers approximately 5%, and Actinobacteria represents about 3% [7].

The effect of exercise on the Gut Microbiota

In a study by Estaki and colleagues [8], they found that in healthy individuals, higher levels of cardiorespiratory fitness, measured by peak or maximum oxygen uptake (VO2peak or VO2max), were linked to increased microbial diversity and fecal butyrate. Notably, individuals with greater fitness levels exhibited a core set of gene-related functions rather than a specific set of bacterial species. Around 20% of the variation in gut bacterial diversity could be explained by VO2peak alone, with VO2peak being the most significant contributor to increased alpha diversity, outperforming variables like sex, age, BMI, and various dietary components. This suggests that cardiorespiratory fitness is a reliable predictor of gut microbial diversity in healthy individuals.

The study also revealed positive correlations between enhanced bacterial diversity and certain microbial metabolic functions, such as chemotaxis, motility, and fatty acid biosynthesis. Although VO2peak wasn't significantly associated with changes in the community composition, it appeared that function could better predict outcomes than species richness. These findings echoed earlier results by Matsumoto and colleagues [9], demonstrating that exercising rats with high cardiorespiratory fitness showed increased levels of the short-chain fatty acid butyrate, linked to higher abundances of specific bacterial groups.

The functional categories most strongly linked to VO2peak were related to bacterial motility, sporulation, and a bacterial communication system responding to environmental factors. One potential explanation for these associations is that the abundance of butyrate, more prevalent in individuals with higher cardiorespiratory fitness, could influence neutrophil chemotaxis. Moreover, VO2peak showed an inverse correlation with the biosynthesis of lipopolysaccharides (LPS) and associated proteins. Elevated levels of LPS, found in less fit individuals, can trigger inflammatory responses that may contribute to obesity and metabolic syndromes. Exercise training, by reducing elevated blood LPS, is suggested to alleviate inflammation. Therefore, the inverse relationship between VO2peak and LPS biosynthesis pathways suggests a positive outcome of increased physical activity, potentially leading to decreased LPS biosynthesis.

The Reciprocal Connection Between Exercise and the Microbiome

For a while now, people have noticed that physical activity can significantly impact gut well-being, even being suggested as a remedy for several chronic digestive conditions [10]. The influence of exercise on gut health and immunity is often described as a "J-curve," implying that a moderate level of activity positively addresses issues like gut permeability and inflammation, while intense and prolonged exercise can have negative effects [11-13]. This is evident in elite endurance athletes who frequently face various digestive problems during or after intense workouts. In a study during a 161 km ultramarathon, around 96% of participants experienced gastrointestinal symptoms, with 35.6% attributing their inability to finish the race to these issues [14].Conversely, a study found that sedentary individuals with normal body composition had higher serum endotoxin levels compared to trained cyclists, supporting the idea that exercise has a hormetic impact on gut health [15]. The adverse symptoms linked to strenuous exercise are thought to result from a shift in blood flow, causing reduced circulation to the gut, known as intestinal ischemia [16,17]. This, in turn, leads to heightened gut inflammation and permeability [18]. While intestinal ischemia was once believed to be the main contributor to exercise-related digestive problems, there's growing evidence pointing to the involvement of the gut microbiome. Notably, studies have demonstrated that mice without germs or those treated with specific probiotics were resistant to issues related to gut ischemia [19]. Probiotics, described as "live microorganisms that, when given in sufficient amounts, provide health benefits to the host," have shown promise in protecting against digestive distress and upper respiratory tract infections (URTIs) in athletes when taken before races, although the exact mechanisms are not yet fully understood [20-22].

The Microbiome, Respiratory Tract Infection and Inflammation

The impact of probiotics on training and performance is noteworthy [23]. Various studies highlight the significant protective role of specific probiotics against upper respiratory tract infections (URTIs), possibly due to their specific immune-regulating properties [24]. For instance, Tavares-Silva and colleagues discovered that a blend of probiotics (Lactobacillus acidophilus LB-G80, Lacticaseibacillus paracasei LPc-G110, Lactococcus lactis LLL-G25, Bifidobacterium animalis subsp. Lactis BL-G101, and Bifidobacterium bifidum BB-G90) led to a substantial decrease in URTI symptoms and a 29% reduction in URTI incidents among marathon runners [25].

The prevalence of URTIs and gastrointestinal issues is thought to be closely linked to chronic systemic inflammation, partly attributed to increased gut permeability from intense exercise. Pro-inflammatory molecules, like bacterial lipopolysaccharides, can enter circulation, causing chronic low-grade inflammation. Probiotics have shown promise in lessening this inflammatory response, potentially mitigating the negative consequences, reducing gastrointestinal symptoms, and lowering URTI occurrence/severity [11]. This suggests that anti-inflammatory pre-/probiotics could directly benefit by reducing the performance decline associated with chronic inflammation. Moreover, there might be an indirect benefit from a reduced need for standard anti-inflammatory drugs, known to significantly impact the gut microbiome [26].

In summary, these findings indicate the potential of specific probiotics to decrease URTI incidents and inflammation, thereby minimizing their impact on performance.

Exercise and Gut Physiology

Gentle physical activity can impact the digestive system by decreasing the time it takes for stool to pass through, reducing the exposure of pathogens to the gastrointestinal mucus layer. This suggests that exercise has a protective role, lowering the chances of developing conditions like colon cancer, diverticulosis, and inflammatory bowel disease [27]. Even when combined with a high-fat diet, exercise may help diminish inflammatory effects and safeguard the structure and health of the intestine [28]. Sedentary behavior, coupled with a high-fat diet, is linked to changes in intestinal structure, but exercise can counteract these changes by reducing the expression of a specific enzyme (Cox-2) in different parts of the gut [28]. On the other hand, endurance exercise can alter the gastrointestinal tract by significantly decreasing blood flow, potentially causing harmful effects [27]. This reduction is tied to increased resistance in the blood vessels of the gastrointestinal area, influenced by heightened activity from the sympathetic nervous system [27]. Prolonged exercise can also elevate intestinal permeability, jeopardizing the function of the gut barrier and leading to the movement of bacteria from the colon to other parts of the body [27, 29].

Influence of Sports Nutrition on Gut Microbiota

In essence, there’s a need for more extensive, prolonged studies involving diverse groups of athletes to explore how diet influences the structure and function of the gut microbiota. This becomes crucial given the unique dietary practices many athletes adopt, especially during heightened training leading up to competitions and off-season periods. It’s essential for research to delve into the intricate interactions between exercise and nutrients that drive adaptation and performance [30]. Moreover, there’s a call for additional investigations into the synthesis kinetics and clinical implications of microbial by-products under increased nutritional demands and metabolic stress during exercise. Ultimately, the possibility of tailoring dietary recommendations for athletes by modulating the microbiota and its fermentation capacity is a potential avenue. This could involve suggesting specific nutrients to enhance performance by boosting certain metabolites during exercise and recovery while minimizing those that generate harmful metabolites, exacerbating the impacts of exercise stress [31].

Diet has a well-established role in shaping the composition and activity of gut microbiota, with noticeable changes occurring within 24 hours of a dietary shift. Surprisingly, the influence of energy balance, particularly in athletes affected by RED-S (Relative Energy Deficiency in Sport), has been overlooked. Investigating the impact of total energy consumption without accounting for dietary variations proves challenging, if not impossible. The effects of high-protein intake, especially in the absence of high fat, on gut bacteria require more exploration, along with understanding the consequences of combined high-protein and high-fiber intake. Protein intake appears to strongly influence microbiota diversity, with potential benefits observed in studies on protein supplementation like whey, emphasizing the need for further human-focused research.

Proteins from plant sources significantly impact gut microbiota but necessitate in-depth study within the athlete population. Future investigations should also scrutinize the types and quantities of fats consumed alongside protein to understand their combined effect on the gut microbiota. Increased dietary fiber intake correlates with enhanced microbial richness and diversity. Additionally, athletes with higher carbohydrate and dietary fiber intake seem to exhibit increased abundance of Prevotella. The intricate effects of fats on the gut microbiota are challenging to isolate, but the types of fats consumed are emerging as crucial factors to explore further.

Conclusion

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Reference

1. Brüls, T.; Weissenbach, J. The human metagenome: Our other genome? Hum. Mol. Genet. 2011, 20, 142–148. [CrossRef] [PubMed]
2. Prats, G. Microbiologia y Parasitología Médica; Médica Panamericana: Madrid, Spain, 2012; ISBN 9788498354294.
3. Sebastián-Domingo, J.J.; Sánchez-Sánchez, C. From the intestinal flora to the microbiome. Rev. Esp. Enferm. Dig. 2018, 110, 51–56. [CrossRef] [PubMed]
4. Richmond, C.R. ICRP report of the task group on reference man. Int. J. Nucl. Med. Biol. 1985, 12, 251. [CrossRef]
5. Hopkins, M.J.; Macfarlane, G.T.; Furrie, E.; Fite, A.; Macfarlane, S. Characterisation of intestinal bacteria in infant stools using real-time PCR and northern hybridisation analyses. FEMS Microbiol. Ecol. 2005, 54, 77–85. [CrossRef]
6. Stephens, R.W.; Arhire, L.; Covasa, M. Gut Microbiota: From Microorganisms to Metabolic Organ Influencing Obesity. Obesity 2018, 26, 801–809. [CrossRef]
7. Sun, J.; Kato, I. Gut microbiota, inflammation and colorectal cancer. Genes Dis. 2016, 3, 130–143. [CrossRef]
8. Estaki M, Pither J, Baumeister P, Little JP, Gill SK, Ghosh S, et al. Cardiorespiratory fitness as a predictor of intestinal microbial diversity and Distinct metagenomic functions. Microbiome. 2016;4(1):42 https://doi.org/10. 1186/s40168-016-0189-7.
9. Matsumoto M, Inoue R, Tsukahara T, Ushida K, Chiji H, Matsubara N, et al. Voluntary running exercise alters microbiota composition and increases n-Butyrate concentration in the rat cecum. Biosci Biotechnol Biochem. 2008;72(2):572–6 https://doi.org/10.1271/bbb.70474.
10. Bilski J, Brzozowski B, Mazur-Bialy A, Sliwowski Z, Brzozowski T. The role of physical exercise in inflammatory bowel disease. Biomed Res Int. 2014 doi: 10.1155/2014/429031. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
11. Chamorro-Viña C, Fernandez-del-Valle M, Tacón AM. Excessive exercise and immunity: the J-shaped curve. Active Female. 2014 doi: 10.1007/978-1-4614-8884-2_24. [CrossRef] [Google Scholar]
12. Keirns BH, Koemel NA, Sciarrillo CM, Anderson KL, Emerson SR. Exercise and intestinal permeability: another form of exercise-induced hormesis? In: American Physiological Society [Internet]. 5 Oct 2020 [cited 1 Apr 2022]. 10.1152/ajpgi.00232.2020. [PubMed]
13. Clauss M, Gérard P, Mosca A, Leclerc M. Interplay between exercise and gut microbiome in the context of human health and performance. Front Nutr. 2021;8:637010. Doi: 10.3389/fnut.2021.637010. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
14. Stuempfle KJ, Hoffman MD. Gastrointestinal distress is common during a 161-km ultramarathon. J Sports Sci. 2015;33:1814–1821. Doi: 10.1080/02640414.2015.1012104. [PubMed] [CrossRef] [Google Scholar]
15. Lira FS, Rosa JC, Pimentel GD, Souza HA, Caperuto EC, Carnevali LC, Jr, et al. Endotoxin levels correlate positively with a sedentary lifestyle and negatively with highly trained subjects. Lipids Health Dis. 2010;9:82. Doi: 10.1186/1476-511X-9-82. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
16. De Oliveira EP, Burini RC. Food-dependent, exercise-induced gastrointestinal distress. J Int Soc Sports Nutr. 2011;8:12. Doi: 10.1186/1550-2783-8-12. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
17. Moses FM. Exercise-associated intestinal ischemia. Curr Sports Med Rep. 2005;4:91–95. Doi: 10.1097/01.CSMR.0000306079.74945.ea. [PubMed] [CrossRef] [Google Scholar]
18. Jeukendrup AE, Vet-Joop K, Sturk A, Stegen JH, Senden J, Saris WH, et al. Relationship between gastro-intestinal complaints and endotoxaemia, cytokine release and the acute-phase reaction during and after a long-distance triathlon in highly trained men. Clin Sci. 2000;98:47–55. Doi: 10.1042/CS19990258. [PubMed] [CrossRef] [Google Scholar]
19. Nadatani Y, Watanabe T, Shimada S, Otani K, Tanigawa T, Fujiwara Y. Microbiome and intestinal ischemia/reperfusion injury. J Clin Biochem Nutr. 2018;63:26–32. Doi: 10.3164/jcbn.17-137. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
20. Schreiber C, Tamir S, Golan R, Weinstein A, Weinstein Y. The effect of probiotic supplementation on performance, inflammatory markers and gastro-intestinal symptoms in elite road cyclists. J Int Soc Sports Nutr. 2021 doi: 10.1186/s12970-021-00432-6. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
21. Sivamaruthi BS, Kesika P, Chaiyasut C. Effect of probiotics supplementations on health status of athletes. Int J Environ Res Public Health. 2019 doi: 10.3390/ijerph16224469. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

22. Tavares-Silva E, Caris AV, Santos SA, Ravacci GR, Thomatieli-Santos RV. Effect of multi-strain probiotic supplementation on URTI symptoms and cytokine production by monocytes after a marathon race: a randomized, double-blind, placebo study. Nutrients. 2021;13:1478. Doi: 10.3390/nu13051478. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
23. Gałązka-Franta A, Jura-Szołtys E, Smółka W, Gawlik R. Upper respiratory tract diseases in athletes in different sports disciplines. J Hum Kinet. 2016;53:99–106. Doi: 10.1515/hukin-2016-0014. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
24. Azad MAK, Sarker M, Wan D. Immunomodulatory effects of probiotics on cytokine profiles. Biomed Res Int. 2018;2018:8063647. Doi: 10.1155/2018/8063647. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
25. Tavares-Silva E, Caris AV, Santos SA, Ravacci GR, Thomatieli-Santos RV. Effect of multi-strain probiotic supplementation on URTI symptoms and cytokine production by monocytes after a marathon race: a randomized, double-blind, placebo study. Nutrients. 2021;13:1478. Doi: 10.3390/nu13051478. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
26. Maseda D, Ricciotti E. NSAID–gut microbiota interactions. Front Pharmacol. 2020 doi: 10.3389/fphar.2020.01153. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
27. Peters H. P. F., De Vries W. R., Vanberge-Henegouwen G. P., Akkermans L. M. A. Potential benefits and hazards of physical activity and exercise on the gastrointestinal tract. Gut. 2001;48(3):435–439. Doi: 10.1136/gut.48.3.435. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
28. Campbell S. C., Wisniewski P. J., Noji M., et al. The effect of diet and exercise on intestinal integrity and microbial diversity in mice. PLoS ONE. 2016;11(3):1–17. Doi: 10.1371/journal.pone.0150502.e0150502 [PMC free article] [PubMed] [CrossRef] [Google Scholar]
29. Gisolfi C. V. Is the GI system built for exercise? Physiology. 2000;15(3):114–119. [PubMed] [Google Scholar]
30. Burke LM, Hawley JA, Jeukendrup A, Morton JP, Stellingwerff T, Maughan RJ. Toward a common understanding of diet-exercise strategies to manipulate Fuel availability for training and competition preparation in endurance sport.Int J Sport Nutr Exerc Metab. 2018;28(5):451–63 https://doi.org/10.1123/Ijsnem.2018-0289.
31. Clark A, Mach N. Exercise-induced stress behavior, gut-microbiota-brain axis and diet: a systematic review for athletes. J Int Soc Sports Nutr. 2016;13:43 https://doi.org/10.1186/s12970-016-0155-6.