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The Impact of Physical Activity on Gut Microbiota: An In-Depth Literature Review

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Abstract

Introduction. The human body is home to a diverse community of microorganisms known as the microbiota. These microorganisms, including bacteria, fungi, and viruses, play crucial roles in maintaining overall health. They colonize the digestive tract shortly after birth, and the composition of the gut microbiota changes throughout an individual's life, largely influenced by diet and physical activity. Breastfeeding has long-term beneficial effects on the gut microbiota and gene expression in intestinal cells. Regular exercise not only improves cardiovascular and respiratory health but also affects metabolic, immunological, neural, and microbial pathways. This review explores how diet and physical activity impact the composition and diversity of gut microbiota, highlighting important findings and their implications for health.

Aim of study. This study aims to review how physical activity influences gut microbiota, investigating the effects of different types and intensities of exercise on microbial composition and diversity, and their implications for overall health.

Materials and methods. A non-systematic examination of the scientific literature was conducted using specific keywords such as gut microbiota, physical activity, sport, and microbiome. The examination took place on PubMed, with scrutiny of a total of 31 references published up to 2023.

Conclusions. This review highlights the crucial role of gut microbiota in maintaining good health and its complex interaction with diet and physical activity. Regular exercise has a positive impact on the diversity of microbiota, especially when started at a young age. Imbalance in gut bacteria is linked to various diseases, underscoring the significance of a healthy microbiome. Encouraging physical activity and a nutritious diet can improve gut health, and more research is needed to understand the mechanisms and potential health indicators involved.

KEY WORDS: gut microbiota, guts, physical activity, sport, microbiome

INTRODUCTION

The human body is host to a diverse community of microorganisms that play vital roles in maintaining overall health. This community, known as the microbiota, consists of a complex interplay of bacteria, fungi, and viruses. The colonization of the digestive tract by microorganisms begins shortly after birth, although the precise composition of the initial microbiota remains incompletely understood due to limitations in diagnostic capabilities [1]. Notably, breastfeeding has been associated with beneficial effects on the gut microbiota, with enduring advantages observed in the maintenance of a healthy gut and the regulation of gene expression in intestinal cells, suggesting lasting benefits to the intestinal immune system of breast-fed infants that persist into adulthood [4].

The composition of the microbiome is subject to change throughout an individual's lifespan, with dietary patterns exerting a notable influence. For instance, consumption of animal-based or plant-based foods has been shown to impact the composition of the gut microflora [2]. Moreover, related individuals exhibit a high degree of similarity in the composition of microorganisms inhabiting their digestive system [3].

Regular physical exercise confers numerous advantages that extend beyond the enhancement of cardio-respiratory health, affecting various organ systems by engaging metabolic, immunological, neural, and microbial pathways [5]. Changes in dietary intake and levels of physical activity have been demonstrated to influence the composition of the gut microbiota, thereby affecting its diversity and similarity.

Notably, research on rats has revealed that a restrictive diet results in significant alterations in the abundance of specific bacterial taxa in the gut [6]. Similarly, exercise has been shown to induce changes in the composition of gut bacteria in rats, with distinct bacterial taxa becoming more or less prevalent following exercise [7]. Furthermore, it has been demonstrated that the gut microbiota is more susceptible to alterations induced by physical exercise during early life compared to later stages of development [8].

ROLE OF GUT MICROBIOTA

The gut microbiome plays a critical role in the metabolism of drugs and xenobiotics, which are foreign substances to the body, often administered orally, and significantly affecting the gut microbiome. Enzymes derived from the gut microbiota are involved in the metabolism of various drugs, with lyases being particularly important as they break specific chemical bonds independently of oxidation or addition of water. Enzymes such as polysaccharide lyases (PLs) and glycoside hydrolases, encoded by intestinal microbiota genomes, aid in the breakdown of dietary or mucin glycans. Host-mediated xenobiotic metabolism involves the liver, while gut bacteria-encoded enzymes in the intestine aid in detoxification. Gut bacteria utilize specific enzymes for radical biotransformations, crucial for various metabolic reactions [9, 10, 11].

Moreover, the gut microbiota significantly influences mucosal immunity, impacting the numbers of specific immune cells and the expression of microbicidal proteins. Environmental factors, particularly diet, have a profound impact on the composition and diversity of the gut microbiome, with high-fat and high-sugar diets altering microbial populations and short-chain fatty acid (SCFA) production [12, 13, 14, 15].

Furthermore, the gut microbiota is involved in the synthesis and utilization of vitamin B12, and its impact on the microbiome remains an area of understudy. The unabsorbed vitamin B12 in the large intestine is metabolized by gut bacteria into analogs, potentially impacting microbiota composition and function [16, 17, 18].

GUT MICROBIOME'S INFLUENCE ON VARIOUS DISEASES

In recent years, several studies have indicated that the composition of the gut microbiome can be influenced by specific diseases.

The gut microbiome is implicated in the development of IBD. In a study on mice, researchers transplanted pro-inflammatory microbiota into a group of susceptible mice, which led to the onset of the disease [19]. In another study, germ-free mice were colonized with microbiota from 30 different human donors to compare the functioning of microbiota from individuals with IBD to that from healthy individuals. The results showed that mice colonized with microbiota from IBD patients exhibited a different immune response, including an increase in Th17 cells in the gut and a decrease in RORγt+ Treg cells [20].

Dysbiosis in the gut can contribute to the development of cardiovascular diseases. Individuals with cardiovascular diseases exhibit increased intestinal barrier permeability. Studies have shown that elevated levels of LPS in these patients exacerbate inflammation, which is associated with its release from the gut microbiota [21].

It's crucial to consider the influence of the microbiota on the mental health of adults. Research has demonstrated alterations in the microbiome makeup in individuals with depression. It has been revealed that bacteria from the Lactobacillus and Bifidobacterium genus can have varying impacts on the mental well-being of patients [22].

GUT HEALTH THROUGH PHYSICAL ACTIVITY

The impact of physical activity on the human body is multidimensional. Regular sports participation positively affects both physical and mental health. Research has shown that the benefits of an active lifestyle also stem from its influence on the structure and diversity of the gut microbiota. Microbial diversity may become a new biomarker or health indicator as it affects the stability and efficiency of processes occurring in the body. Loss of biodiversity within the gut is linked to an increasing number of conditions such as autism, gastrointestinal diseases including IBD, recurrent Clostridium difficile, and inflammatory symptoms associated with obesity.

A study conducted on a group of athletes showed that the diversity of the athletes' gut microbiota was significantly higher than in the control group of physically inactive individuals, matched for physical size, age, and gender. It was also noted that athletes in the low BMI group had a significantly higher percentage of Akkermansia bacteria than those in the high BMI group. Akkermansia has been identified as a mucin-degrading bacterium, with its abundance inversely correlated with obesity and associated metabolic disorders in mice and humans. [23]

Interestingly, the diversity of intestinal microbiota in athletes may have a positive impact on their results. Scheiman et al. [24] described an increase in the relative abundance of Veillonella observed in marathon runners after the marathon, and a strain of Veillonella atypica was isolated from fecal samples. It was revealed that V. atypica improves athletic performance by metabolically converting lactate produced during exercise into propionate, thus identifying a natural enzymatic process encoded by the microbiome.

Several studies suggest a bidirectional interaction between skeletal muscles and the gut. During contraction, myokines are released, which have anti-inflammatory effects, and some seem to mediate the secretion of glucagon-like peptide-1 in the gut during exercise. Certainly, interleukin-6 is also involved in the secretion of GLP-1 in the ileum. Gut microbiota also produces SCFAs, which are key mediators of energy metabolism in skeletal muscle mitochondria, in turn helping to regulate glucose metabolism throughout the body. It has been highlighted that the amount of SCFA seems to increase after medium/long-term physical interventions and is positively correlated with the level of physical activity and cardiorespiratory fitness. [25]

Allen et al. [26] proved that 6 weeks of aerobic exercise altered the gut microbiota and microbiologically derived SCFAs in lean and obese adults previously leading a sedentary lifestyle, without any changes in dietary patterns. At the beginning of the study, obese individuals had a different gut microbiota composition compared to lean individuals, and the microbiota in both groups responded differently to physical training. However, it was reported that changes in the gut microbiome that occurred after returning to a sedentary lifestyle were inversely related to changes that occurred in response to exercise, providing further evidence that the level of physical activity significantly contributes to the composition of the human gut microbiota.

An important aspect in the context of microbiota composition is diet, which is closely related to practicing sports. A study comparing the characteristics of the fecal microbiota of healthy men leading a sedentary lifestyle (as a control group), bodybuilders, and long-distance runners, as well as the relationship between microbiota characteristics, body composition, and nutritional status, was conducted by Jang et al [27]. The type of exercise was linked to the dietary habits of the athletes (bodybuilders: high-protein, high-fat, low-carbohydrate, and low-fiber diet; long-distance runners: low-carbohydrate and low-fiber diet). Athlete type did not differ regarding gut microbiota alpha and beta diversity. Athlete type was significantly associated with the relative abundance of gut microbiota at the genus and species level: Faecalibacterium, Sutterella, Clostridium, Haemophilus, and Eisenbergiella were the highest in bodybuilders, while Bifidobacterium and Parasutterella were the lowest. The results suggest that high-protein diets may negatively impact the diversity of athletes' gut microbiota, while resistance-trained athletes following a high-protein and low-carbohydrate diet showed a reduction in the number of commensal bacteria producing short-chain fatty acids. This confirms the close relationship between diet and microbiota.

The age of the individual undertaking physical activity and its impact on the microbiota is also significant. Mika et al. [28] conducted a study on rats which showed that exercise started early in life can have a more pronounced effect on the gut microbiota than exercise started in adulthood. These results support the thesis that the microbiota is more plastic and sensitive to changes early in life. Considering that starting exercise at a young age produced microbial patterns associated with leanness and lasting increases in lean mass, exercise-induced changes in the microbiota early in life may potentially contribute to lasting metabolic consequences.

Most scientific reports on the impact of exercise on the microbiota focus on regular, long-term changes in activity levels. However, studies suggest that even a single intense physical effort can affect the composition and functions of the gut microbiota. Various experimental studies on both animals and humans have shown that physical activity can induce changes in the gut flora shortly after its performance. A study evaluating the impact of endurance running, such as marathon running, on human gut microbial communities was conducted by Zhao et al. [29]. Many findings demonstrated that marathon running immediately causes metabolic changes in the blood, urine, muscles, and lymph, which potentially affect the gut microbiota within a few hours. It was found that after completing a half-marathon, 40 metabolites in the feces significantly changed. Running-induced gut changes did not affect alpha diversity, but the abundance of some microbiota representatives significantly differed before and after the run. They observed a significantly increased species richness after running in the families Coriobacteriaceae and Succinivibrionaceae. The Coriobacteriaceae family has been identified as a potential biomarker linking exercise with health improvement. These findings highlighted the health benefits of exercise from the perspective of the microbiota.

However, there are reports that physical activity does not increase the richness of microbiota. Bressa et al. [30] tested whether exercise practiced at a dose recommended by WHO was sufficient to alter the composition of the gut microbiota in women. The results presented show that physical activity modulates the microbiota profile but they failed to find an increase in microbiota richness. Their results indicate that physical activity performed at low doses but continuously can increase the abundance of health-promoting bacteria (Bifidobacterium spp, R. hominis, A. muciniphila,F. prausnitzii) in the microbiota. They found an inverse association between sedentary parameters and microbiota richness (number of species, and

Shannon and Simpson indices), which might indicate that perhaps not only is the dose and mode of exercise important, but also the pattern of exercise, such as breaks in sedentary time, avoiding long periods of inactivity in daily life, to induce changes in gut microbiota.

Similar results were obtained by Welly et al. [31]. No difference was found between groups in alpha diversity, suggesting that physical activity did not affect species richness in cecal microbiota. However, weighted principal coordinates analysis (PCoA) showed that the beta diversity of gut microbial communities was significantly different. These PCoA results suggested that the abundance of the bacteria, and not the presence of rare taxa, was the driving force of the differences observed.

CONCLUSIONS

This literature review emphasizes the crucial role of gut microbiota in overall health and its dynamic relationship with various factors such as diet and physical activity. The composition of the microbiota is significantly influenced by breastfeeding from birth, providing long-lasting benefits to gut health and immune regulation. Throughout life, dietary patterns continue to shape the microbiome, with noticeable differences between those consuming animal-based and plant-based diets.

Physical activity has been found to significantly influence the gut microbiota. Engaging in regular exercise not only benefits heart and lung health, but also affects metabolic, immune, neural, and microbial pathways. Research on both animals and humans has demonstrated that both diet and exercise can cause significant changes in the composition and diversity of gut microbiota. These changes are more noticeable when physical activity is initiated early in life, indicating a critical period during which the microbiota may be more responsive to beneficial modifications.

The gut microbiota plays a crucial role in metabolizing drugs and xenobiotics. Disruption or dysbiosis of the gut microbiota has been associated with various diseases such as cardiovascular diseases, inflammatory bowel disease (IBD), and mental health disorders. This emphasizes the link between physical activity, diet, and gut microbiota, and the potential to use these connections to enhance health outcomes.

In summary, encouraging regular physical activity and a balanced diet may be crucial in maintaining a healthy and diverse gut microbiota, ultimately contributing to improved physical and mental health. Further research is necessary to investigate the mechanisms underlying these interactions and to identify specific microbial markers that could be used as indicators of health status.

DISCLOSURE

Author's contribution

Iwona Lenartowicz: Conceptualization, writing rough preparation, **Patrycja Brzozowska**: Writing rough preparation, formal analysis, **Agata Frańczuk**: supervision, resources

Bianka Nowińska: visualization, data curation

Aleksandra Makłowicz: Methodology, software, check

Karolina Alicja Palacz: writing and editing,

Project administration: Karolina Alicja Palacz

All authors have read and agreed with the published version of the manuscript.

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The authors deny any conflict of interest

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