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Advances in Research on the Relationship between Diet, Gut Microbes, and Health

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Abstract: In recent years, as research on gut microbiota has deepened, the relationship between diet, gut microbiota, and health has garnered widespread attention. As the largest micro-ecosystem in the human body, gut microbiota not only participates in physiological processes such as food digestion and nutrient absorption but also exerts a profound impact on human health through its metabolic products and interactions with the host. This paper reviews the impact of diet on gut microbiota, and the relationship between gut microbiota and health, aiming to provide new strategies and ideas for promoting human health. Firstly, the article summarizes the effects of different dietary components and dietary patterns on the structure and function of gut microbiota. Then, it analyzes the role of gut microbiota in maintaining human health and preventing diseases and further explores the relationship between gut microbiota and intestinal diseases and metabolic syndrome. The analysis reveals that diet affects human health by influencing the structure and function of gut microbiota, while gut microbiota, as a complex ecosystem within the human body, plays an indispensable role in maintaining human health.

Keywords: Diet; Gut microbiota; Health; Microbial community structure; Function; Disease

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1. Introduction

With the continuous advancement of modern biomedical research, the relationship between gut microbiota and health has gradually become a focal point in the field of scientific research and public concern. Gut microbiota, as “invisible residents” in the human body, are closely related to our diet and profoundly affect human physiological functions and health status. In recent years, numerous studies have shown that differences in dietary habits lead to changes in the composition of gut microbiota, which in turn are closely linked to the health of multiple systems in the human body, including metabolic, immune, and even nervous systems. Therefore, exploring the relationship between diet, gut microbiota, and health in depth has significant theoretical and practical implications for improving the overall health level of humans.

2. The impact of diet on gut microbiota

2.1. The impact of dietary components on the structure of the gut microbiota

2.1.1. Protein

Protein affects the structure of gut microbiota, and different sources and types of protein have varying effects on gut microbiota. For instance, a long-term high animal protein diet may increase the number of harmful bacteria in the gut, such as sulfate-reducing bacteria, which may produce harmful substances like hydrogen sulfide, negatively impacting human health. On the other hand, a plant protein diet helps promote the growth of beneficial bacteria, such as *Bifidobacterium* and *Lactobacillus*, thereby maintaining gut health.

2.1.2. Fat

Fat intake influences the structure of gut microbiota. A high-fat diet may lead to an increase in the proportion of *Bacteroidetes* and *Firmicutes* in the gut, which are associated with an increased risk of chronic diseases like obesity and cardiovascular diseases. Wang Weiwei *et al*. [1] studied the effect of different fat energy ratios in diets on fat metabolism and gut microbiota in rats. They found that when the fat-to-carbohydrate ratio in the diet exceeded 30%, it reduced the abundance of beneficial bacteria in the gut and increased the abundance of potentially pathogenic bacteria.

2.1.3. Carbohydrates

Carbohydrates are an essential component of the diet and have a significant impact on gut microbiota. Different types of carbohydrates, such as simple sugars, complex polysaccharides, and dietary fibers, have varying effects on the composition and activity of gut microbiota. A high dietary fiber diet can increase the number of beneficial bacteria in the gut, such as *Bifidobacterium* and *Lactobacillus*. For example, An Yang *et al*. [2] analyzed the intervention effect of high dietary fiber, and low glycemic index coarse grains on the gut microbiota of people with prediabetes. They found that these foods could adjust the gut microbiota structure, support beneficial gut bacteria, inhibit opportunistic pathogens, and restore the gut microecology. Conversely, a high-sugar diet may promote the growth of harmful bacteria. Ma Xianyi *et al.* [3] explored the impact of high-sugar feed prepared with starch as the main sugar source on the growth and gut microbiota structure of yellow catfish. They found that long-term consumption of high-sugar feed inhibited the growth of yellow catfish, reduced feed utilization, altered the composition and structure of gut microbiota, and increased the risk of disease infection.

Additionally, specific types of carbohydrates, such as oligosaccharides, also affect gut health. Yi Jianhong [4] studied the effect of exogenous xylo-oligosaccharides on the gut microenvironment of white feather broilers. They found that adding 300 mg/kg of xylo-oligosaccharides to the broilers' diet effectively increased the number of beneficial bacteria (e.g., *Lactobacillus* and *Bifidobacterium*) while inhibiting the growth of harmful bacteria (e.g., *Enterococcus* and *Escherichia coli*), increased microbial diversity, and maintained the balance of gut microbiota, thus improving gut health. These findings are consistent with those of Yu Chunlin *et al.* [5].

2.2. The impact of dietary patterns on gut microbiota functions

2.2.1. Vegetarian diet

A vegetarian diet, which primarily includes plant-based foods such as grains, legumes, nuts, vegetables, and fruits, positively impacts gut microbiota function. On one hand, a vegetarian diet is rich in dietary fiber, which is difficult for the human body to digest and absorb but serves as a nutrient source for gut microbiota. By promoting the growth of beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*, a vegetarian diet helps maintain the balance of gut microbiota and reduces the number of harmful bacteria, thereby enhancing the gut

barrier function. On the other hand, a vegetarian diet also contains abundant vitamins and minerals, which are crucial for the metabolic activities of gut microbiota. For example, vitamins B and K are key substances for the synthesis of certain essential nutrients by gut microbiota, while minerals such as zinc and iron are important for the metabolic processes of gut microbiota. Therefore, a vegetarian diet helps improve the metabolic function of gut microbiota, promoting gut health.

2.2.2. Meat-based diet

A meat-based diet, which primarily includes animal-based foods such as red meat, poultry, and fish, has some negative impacts on gut microbiota function compared to a vegetarian diet. Firstly, animal-based foods like red meat are rich in saturated fats and cholesterol, excessive intake of which may lead to an imbalance in gut microbiota. Specifically, a high-fat diet may increase the proportion of *Bacteroidetes* and *Firmicutes* in the gut, which are associated with an increased risk of chronic diseases such as obesity and cardiovascular diseases. Additionally, saturated fats may inhibit the growth of beneficial bacteria, reducing the diversity of gut microbiota [6]. Moreover, processed meat products and animal offal in a meat-based diet may contain high levels of salt and nitrates, which can harm gut microbiota and inhibit their normal growth and metabolic activities. Therefore, long-term excessive consumption of a meat-based diet may adversely affect the function of gut microbiota.

2.2.3. Impact of the Mediterranean diet on gut microbiota function

The Mediterranean diet, a healthy dietary pattern, primarily includes grains, legumes, nuts, vegetables, and fruits, supplemented with moderate amounts of fish and poultry. This dietary pattern positively impacts gut microbiota function [7]. On one hand, the Mediterranean diet is rich in dietary fiber, vitamins, and minerals, which help maintain the normal growth and metabolic activities of gut microbiota. By promoting the growth of beneficial bacteria and inhibiting the proliferation of harmful bacteria, the Mediterranean diet helps maintain the balance and stability of gut microbiota. On the other hand, the healthy fats in the Mediterranean diet, such as olive oil, contain abundant unsaturated fatty acids, which positively influence the metabolic activities of gut microbiota. Unsaturated fatty acids can increase the number and activity of beneficial bacteria in the gut, promoting gut health. Additionally, healthy fats like olive oil have antioxidant and anti-inflammatory properties, which can further protect gut microbiota from damage.

3. The relationship between gut microbiota and health

3.1. Gut microbiota and health status

Gut microbiota play a multifaceted role in maintaining human health and preventing diseases. Firstly, gut microbiota secretes various cytokines and enzymatic molecules that participate in the body's immune response, maintaining internal environmental stability. They can regulate the development and maturation of the host's immune organs and stimulate the host to produce immune responses, including humoral and cellular immunity, as broad-spectrum antigens. Secondly, gut microbiota ferments unabsorbed carbohydrates in the digestive system, producing beneficial components such as short-chain fatty acids, which are crucial for host nutrient metabolism [8]. They can also synthesize various vitamins, amino acids, and peptides, and promote the absorption of minerals and nutrients, thereby influencing the host's nutrient metabolism. Additionally, gut microbiota closely interact with the host to form a complex microecological environment, maintaining the integrity of the intestinal epithelium and mucosal homeostasis. Certain gut microbiota strains can also synthesize neurotransmitters like serotonin, which can influence central nervous system function, thereby affecting mood and behavior. Moreover, gut microbiota have anti-inflammatory effects; for example, some

probiotics can competitively inhibit the overgrowth of harmful bacteria, reducing the frequency of endotoxemia and effectively mitigating inflammatory responses [9].

3.2. Gut microbiota and diseases

3.2.1. Gut microbiota and intestinal diseases

Gut microbiota plays a crucial role in the onset and progression of intestinal diseases. Studies have found that the gut microbiota composition of patients with inflammatory bowel disease (IBD) differs significantly from that of healthy individuals. These differences manifest as the overgrowth of certain harmful bacteria and a decrease in beneficial bacteria. These harmful bacteria may promote the occurrence and development of intestinal inflammation by releasing inflammatory factors and damaging the intestinal mucosal barrier [10]. Research indicates that patients with irritable bowel syndrome (IBS) have reduced gut microbiota diversity and changes in the quantity of specific bacterial groups [11]. These changes may be related to factors such as abnormal intestinal motility and impaired intestinal mucosal barrier function.

Related studies have shown that regulating the balance of gut microbiota, such as using probiotics and prebiotics, can improve the intestinal environment, reduce intestinal inflammation and symptoms, and is of great significance for the prevention and treatment of intestinal diseases [12,13].

3.2.2. Gut microbiota and metabolic syndrome

Metabolic syndrome is a group of metabolic diseases characterized mainly by obesity, hypertension, hyperglycemia, and hyperlipidemia, and there is a close relationship between gut microbiota and metabolic syndrome [14]. The gut microbiota composition of obese individuals differs significantly from that of healthy individuals. In the gut of obese people, the number of microorganisms that promote energy absorption and storage increases, while the number of microorganisms that help energy expenditure decreases. These changes may lead to an imbalance between energy intake and expenditure, thereby promoting the occurrence of obesity.

Diabetic patients also exhibit an imbalance in gut microbiota. The number of certain beneficial bacteria, such as *Bifidobacterium*, decreases, while the number of some potentially harmful bacteria, such as *Clostridium*, increases. These changes may affect the function of the intestinal mucosal barrier, leading to abnormal glucose absorption and insulin resistance, thereby promoting the onset and progression of diabetes [15]. By improving dietary structure, increasing dietary fiber intake, and using probiotics, the balance of gut microbiota can be regulated, improving the intestinal environment of patients with metabolic syndrome. This helps lower blood sugar and lipid levels and is beneficial for the prevention and treatment of metabolic syndrome [16].

4. Conclusion

Research on the relationship between diet, gut microbiota, and health is rapidly advancing, with new findings continually emerging, providing us with more insights into the interactions between a healthy diet and gut microbiota. However, this field still faces many challenges, such as how to accurately assess the structure and function of gut microbiota and how to quantify the impact of different dietary habits on gut microbiota. In the future, with continuous technological advancements and deeper research, we hope to uncover more details about this relationship and develop more scientific and effective dietary strategies for health.

Disclosure statement

The author declares no conflict of interest.

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