Gut microbiota: Influences, health implications, and multiomics approaches


Pragati Kumari, Dr. Seema Rohilla*
Geeta Institute of Pharmacy, Geeta University, Naultha-132145, Panipat, Haryana, India
E-mail address: seemarohilla4@gmail.com

Abstract

Gut microbiota comprises microorganisms throughout the gastrointestinal tract, influencing human health. Factors like diet, medication, and illnesses impact its balance. Changes in the microbiota relate to diseases such as diabetes, obesity, gastrointestinal disorders, neurodegenerative diseases, and cancer. Studies focus on the microbiota–intestine–brain axis and how diet controls microbiota. Probiotics and prebiotics affect its balance. Aging and diseases cause compositional and functional changes in microbiota. Multiomics approaches are essential to understanding microbial community functions and health connections.

Keywords: Microbiota, probiotics, prebiotics, microbiota-intestine-brain axis etc.

1. Introduction

The gastrointestinal system is colonized by a collection of bacteria known as the gut microbiota, which are more prevalent than human body cells. Numerous studies show that gut microbiota is closely linked to both host health and some diseases because of the diversity of bacteria that make them the most significant environmental agent in the human body (1). Firmicutes, Bacteroidota, Verrucomicrobia, Actinobacteria, and Proteobacteria are the five phyla that make up around half of the faecal bulk, with the first two making about 90% of the total (2, 3).Even though there is evidence that the gut microbiota affects the characteristics of many illnesses, additional study is required to examine other aspects, such as the interactions between host genetics, food, and metabolic control (4,5).The aggregate genomes of the microbiota that reside on and inside different parts of the human body, including viruses, eukaryotes, protozoa, archaea, and mostly bacteria, make up the human microbiome (6,7). It is estimated that the human body hosts around 500 to 1000 bacterial species at any given time, though the number of distinct genotypes (or subspecies) may be several orders of magnitude higher (8).

2. The Gut Microbiota's Function in Human Health

By digesting food, defending against infections, boosting immunity, and generating vitamins, the gut microbiota is essential to good health. Major types include Firmicutes and Bacteroidetes (9). These bacteria maintain balance and support overall wellbeing through diverse functions essential to the body (10). The regional variation in microbiota composition is depicted in Figure 1. Candida, Saccharomyces, Malassezia, and Cladosporium are key fungi studied in human gut microbiota (11). Human gut microbiota also includes viruses, phages, and archaea, mainly M. smithii species (12). The interconnected functions of gut microbiota in health and nutrition are schematically represented in Figure 2.

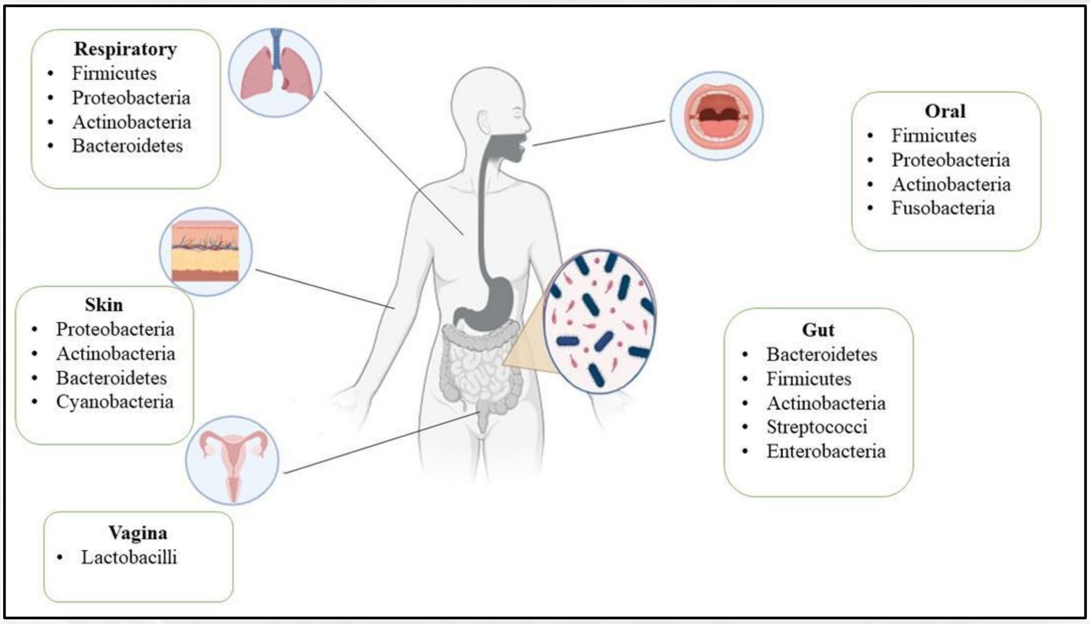

Figure 1. Microbiota Composition in different region

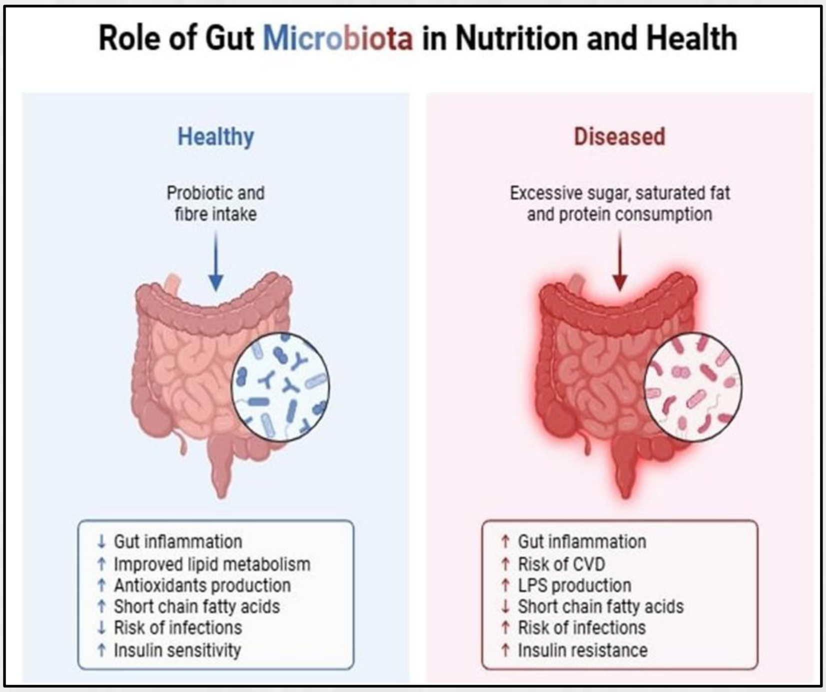

Figure 2. The Gut Microbiota's Function in Nutrition and Health

3. Metagenomic Approach:

The two most common methods used for microbiome community profiling are 16S rRNA amplicon sequencing and shotgun metagenomic analysis. Shotgun sequencing begins with the extraction of DNA from every cell of the sample, followed by its cleavage into tiny pieces and sequencing. The readings are then aligned using computational techniques with reference genomes or marker genes to determine the taxonomic abundances in the sample. It is also possible to build bacterial genomes de novo using shotgun sequencing with deeper read depths. Just a portion of the 16S rRNA gene from bacterial genomes in a sample is amplified and sequenced in 16S rRNA amplicon sequencing. There are conserved and variable regions in the 16S rRNA gene (13). It has been demonstrated that fungi interact intricately with both their host and other microbiome members (14). Additionally, fungi affect the immunity and general health of the host. For instance, Candida species have also been linked to illnesses like liver disease and inflammatory bowel disease. Following data processing and sequencing, microbial abundances can be shown as a two-dimensional matrix of counts, with each cell denoting the estimated abundance of a taxon found in a given sample. The information is then analyzed computationally to extract biological insights. The Key roles of microbiome enlisted in table 1.

Table 1: Key Roles in Human Health

Key Role	Description	References
1. Digestion and Nutrition	Brain-gut microbial interactions affect mood, psychological well-being.	(15)
2. Immune System Regulation	Early immune system development, immune response regulation, and gut barrier integrity protect against pathogens.	(16)
3. Metabolic Functions	Produces necessary amino acids, regulates bile acids, and controls fat deposition and glucose balance.	(17)
4. Protection Against Pathogens	Prevents dangerous bacteria colonization and maintains gut lining health.	(18)
5. Mental Health and Mood	Strong gut-brain axis; gut microorganisms create anxiety, depression, and cognition.	(19)

4. Factors Influencing Gut Microbiome Balance

The creation of the gut microbiome is highly dynamic and impacted by multiple factors, ranging from diet to environmental exposures are shown in fig.3. An imbalance in the microbiome, which is made up of several bacteria that live symbiotically in human bodies, is referred to as ‘dysbiosis’. A balanced variety in which no one species of bacteria, virus, or fungus predominates is a hallmark of a healthy microbiome. Numerous internal and external variables can impact microbiomes, including:

- Antibiotics and agents that kill bacteria
- Other drugs and medications.
- Smoking and alcohol use.
- Toxins in the environment
- Physical and psychological stress.
- Chronic inflammation

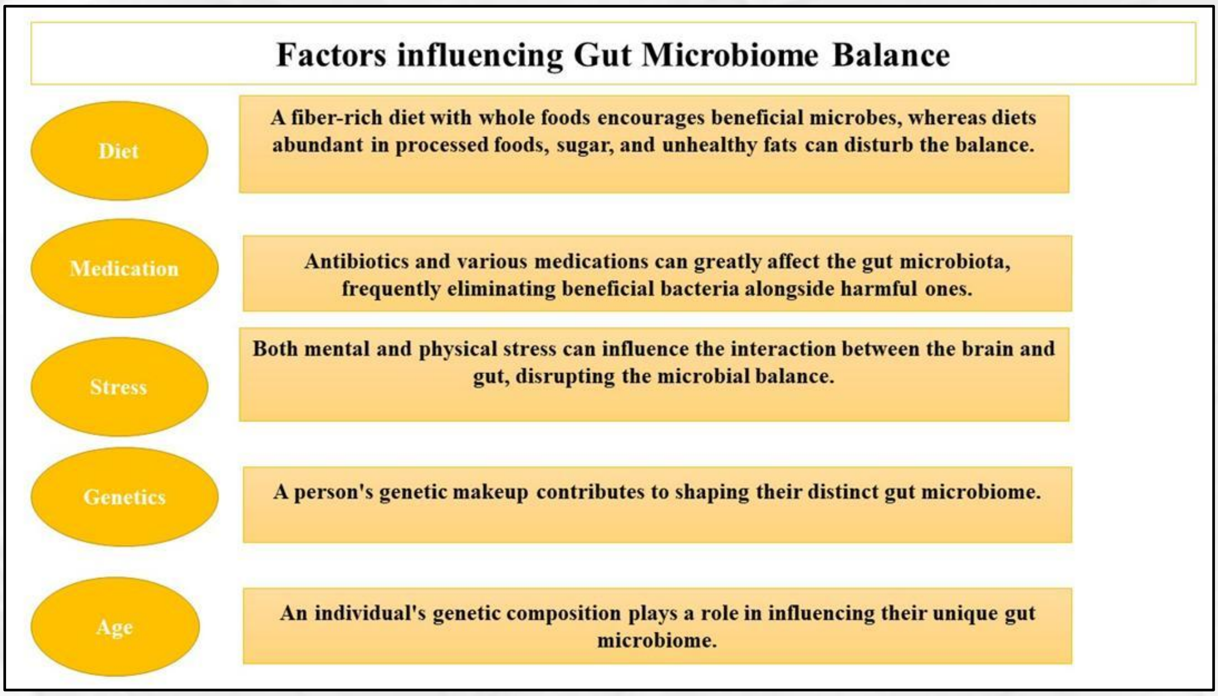

Figure 3: Factors Influencing Gut Microbiome Balance

5. Signs of an Imbalanced Gut Microbiome

Constipation, diarrhoea, gas, and bloating are digestive symptoms that might point to gastrointestinal disorders. Gut abnormalities that impact serotonin levels can cause chronic tiredness and sleep difficulties. Poor gut flora frequently causes food intolerances and sugar cravings, which affect inflammation and weight. Intestinal health may also be linked to skin conditions including psoriasis, eczema, and acne, underscoring the gut's widespread influence on general health.

1. Health Consequences of Dysbiosis

Digestion problems like gas, bloating, diarrhea, and constipation are the most typical signs of bacterial dysbiosis, an imbalance of the body's microbes that can cause a variety of illnesses. Joint discomfort, mental swings (depression, anxiety), and physical issues (eczema, acne) are other symptoms. Chronic illnesses like obesity, type 2 diabetes, and autoimmune diseases have been connected to it along with some gastrointestinal illnesses like Parkinson's disease, rheumatoid arthritis or lupus, inflammatory bowel disease (IBD), asthma, irritable bowel syndrome (IBS), and colon cancer (18-19).

7. Strategies to Restore and Maintain Gut Balance

Diverse microorganisms may support health in a variety of ways, which is why diversity in the gut is important: better brain health, regulation of the immune system, protection from harmful bacteria, improved digestion and nutrient absorption.

Table 2: Some keys to support a healthy gut microbiome.

Key	Summary	Reference
Add more fiber	Prevents constipation, increases microbial diversity, and acts as a prebiotic.	(20)
Stay hydrated	Prevents constipation and aids in the transport of nutrients and mucus.	(21)

Manage stress	Pain, diarrhea, and constipation are symptoms of stress affecting the gut–brain axis. Meditation and relaxation help.	(22)
Get enough sleep	Microbiota linked to sleep quality, insomnia, and circadian rhythm.	(23)
Stay physically active	The gut microbiota is improved by 150–270 minutes of weekly moderate-to-intense physical activity.	(24)
Eat fermented foods	Yogurt, kefir, kimchi, sauerkraut, miso supply probiotics that restore microbial balance.	(25)
Limit processed foods & sugar	Diets high in sugar and fat reduce microbial diversity and encourage dysbiosis.	(26)
Avoid unnecessary antibiotics	Antibiotics alter the microbiota in the gut, reduce beneficial bacteria, and raise the risk of resistance.	(27)
Diversify your diet	Microbial diversity and resilience are boosted by a variety of plant-based foods.	(28)
Moderate alcohol intake	Excess alcohol disrupts gut barrier & microbial balance.	(29)

8. Future Perspectives in Microbiome Research

Further exploration is needed to advance microbiota-targeted human interventions. Factors predicting individual responses to specific interventions are crucial (30). Nutritional interventions may combine dietary approaches with customized probiotics to improve efficacy. Reintroducing missing microbes through probiotic supplements or fermented foods may restore microbial diversity lost through low-MAC diets. Future studies should define a healthy microbiome, prove causation, and examine the advantages and disadvantages of customized diets (31). Integrating multiomics approaches is essential for understanding microbial community functionality. Interventions enhancing physical and mental health can significantly impact individual well- being and public health outcomes (32).

9. Conclusion:

The gut microbiome is a big ecosystem in the human body, which produces cometabolites for the host's benefit and is influenced by food type and microbiota composition. Scientific interest in microbes and diseases has increased, with faecal microbiota transfer, phage therapy, prebiotics, and probiotics being successful in controlling diseases. Factors like diet can disrupt gut microflora, increasing susceptibility to communicable or non-communicable diseases. Studies on gut microbiota are paving the way for personalized medicine targeting gut microbiota to treat various diseases. To overcome this limitation, researchers have developed metagenomic sequencing and GI bacteria culturing methods.

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