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Original Paper

Obesity and Gut Microbiota: A Succinct Evaluation.

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***Abstract*—Obesity has been of global health concern, contributing to a wide range of chronic diseases such as cardiovascular disease, type 2 diabetes, and certain cancers. Recent research has illuminated the complex role of gut microbiota in the development and progression of obesity The gut microbiota tempers host metabolism through mechanisms like fermentation of dietary fibers, production of short-chain fatty acids, and regulation of appetite-related hormones. Addressing obesity through a microbiota-centric approach necessitates comprehensive strategies that integrate dietary modifications, lifestyle intervention and consideration of culture. The gut microbiota affects metabolism and immune function which are crucial for energy regulation and fat storage. This review examines the interplay between obesity and dysbiosis, emphasizing the critical roles of diet and lifestyle as understanding these dynamics informs tailored interventions for obesity prevention and management.**

***Keywords*—obesity, dysbiosis, microbiota, diet, lifestyle**

I. Introduction

The occurrence of overweight and obesity have been of community health concern even before the 21st century. Overweight and obesity are primarily conditions in which one has surplus fat in the body, however, overweight can be distinguished from obesity in terms of body mass index. Obesity is a multifactorial and complex condition characterized by excessive fat accumulation, which has become a major global health issue, with increasing prevalence across all age groups [1]. It is associated with a heightened risk of several chronic diseases, including type 2 diabetes, cardiovascular diseases, and certain types of cancer, placing a significant burden on healthcare systems worldwide [2]. Body mass index (BMI) is one of the means through which body fat can be measured and it is calculated by sharing the weight(kg) of the subject by the height(m2). It is significant to note that BMI for infants and children are expressed in percentile [3]. Though overweight and obesity are effects of excess fat in the body, an adult is said to be overweight when his or her BMI is equal to or greater than 25; while obesity sets in with a BMI of 30 or above. Factors such as energy imbalance, lack of physical activity, genetics are responsible for overweight and obesity [4]. Obesity puts one at risk of health situations such as type 2 diabetes, hypertension, cardiovascular diseases, psychological issues which may include [5] low self-esteem, depression and anxiety.

W.H.O has it that as of 2022, 43% of adults (18 and above) were overweight and 16% of these adults were living with obesity, while about 37 million children under the age of 5 were overweight.

While diet and lifestyle are critical in the progress of obesity, current investigations have tangled gut microbiota and nutrition as a factor influencing body weight and metabolism.

The human gut or gastrointestinal system comprises of millions of microbes which play vital roles in immune function, digestion, absorption of nutrients and metabolism. These microorganisms play a pivotal role in various physiological processes, such as digestion, immune modulation, and metabolism [6]. Imbalances in gut microbiota composition, often influenced by diet, is capable of contributing to obesity by disturbing energy extraction from food and regulating appetite hormones [7]. Disruptions in the microbial ecosystem, known as dysbiosis, have been associated with metabolic disturbances, altered energy balance, and an increased tendency for fat storage, all of which contribute to obesity [8]. Intestinal dysbiosis, characterized by an increase in Firmicutes bacteria and a decrease in Bacteriodetes, alters energy metabolism leading to a greater accumulation of adipose tissue [9]. The gut microbiota may influence host metabolism through mechanisms such as the fermentation of dietary fibers, production of short-chain fatty acids (SCFAs), modulation of appetite-regulating hormones, and regulation of inflammation [11, 12].

II. Composition Of Gut Microbiota And Functions

The gut microbiota in healthy persons is made up of diverse microorganisms, mainly bacteria, but also consist of archaea, fungi, viruses, and other microorganisms. Bacterial composition includes Firmicutes which is abundant in the human gut and is involved in the fermentation of complex carbohydrates, producing short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate, which are vital for gut health and energy metabolism [13]. Bacteroidetes are also key players in carbohydrate fermentation. The balance between Firmicutes and Bacteroidetes has been associated with body weight regulation, with some studies suggesting an increased ratio of Firmicutes to Bacteroidetes in individuals with obesity [14]. Actinobacteria which is thought to play a crucial role in gut health by aiding digestion and contributing to the regulation of the immune system. Proteobacteria includes some potentially pathogenic bacteria like Escherichia coli and Salmonella. An overrepresentation of Proteobacteria is often observed in individuals with dysbiosis, which may contribute to inflammation and metabolic disturbances [15].

Firmicutes and Bacteroidetes represents the majority of the bacterial population [16].

Although they make up a smaller portion of the microbiota, fungi, especially those belonging to the Ascomycota and Basidiomycota groups, are also found in the gut in addition to bacteria. These funguses have functions in immunological regulation, digesting, and bacterial symbiosis. Intestinal fungi regulate immune responses in inflammatory bowel disease (IBD) by enhancing oxidative phosphorylation and glutaminolysis [17].

The gut microbiota performs numerous essential functions, many of which are fundamental to the health of the host. The microbiota aids in the fermentation of carbohydrates into SCFAs, which give the host energy and support metabolic health, as well as the digestion of otherwise indigestible food fibers [18]. It has been recognized that butyrate, has anti-inflammatory properties and is crucial for gut integrity preservation [19].

Gut bacteria interact with the host's immune system to promote a healthy immunological response. Gut bacteria may alter the way food components are absorbed, which could impact energy balance. It aids in appetite management by modifying hormones such as ghrelin and leptin that control hunger and satiety [20]. The microbiome's metabolites can also regulate insulin sensitivity, lipid metabolism, and obesity. The microbiota aids in preventing harmful bacteria and endotoxins from entering the bloodstream by maintaining the integrity of the gut barrier [21]. Increased intestinal permeability, sometimes known as "leaky gut," [22] is commonly associated with dysbiosis, a microbial imbalance that can lead to metabolic disorders including diabetes and obesity as well as systemic inflammation. Overeating and weight gain may result from dysbiosis's interference with these hormone signals. Essential vitamins (such as vitamin K and B vitamins) and other nutrients are synthesized by specific gut bacteria and are vital for metabolic functions and general health [23].

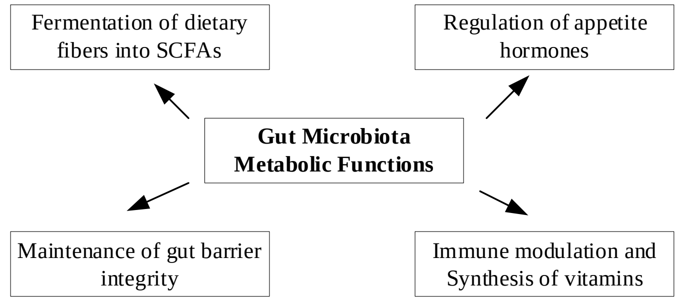

Fig. 1. Gut Microbiota Metabolic Functions

Diet, lifestyle factors, and the genetics of the individual all play significant roles in determining the composition and diversity of the gut microbiota. Dietary habits, particularly fiber intake, [24] influence the abundance of certain bacterial species, such as those involved in fiber fermentation and the production of short-chain fatty acids (SCFAs). Also, the consumption of prebiotics, probiotics, and fermented foods can impact gut microbiota composition [25]. Lifestyle factors such as physical activity, stress levels, and sleep patterns have also been associated with alterations in gut microbiota composition. For example, exercise has shown to encourage microbial diversity and the abundance of beneficial bacteria, while [26] chronic stress can lead to dysbiosis and alterations in gut barrier function.

Although the extent of genetic influence remains incompletely understood, host genetics also contribute to individual differences in gut microbiota composition. Certain genetic variants have been linked to specific microbial taxa, signifying a genetic component to microbiota composition.

The gut microbiota plays indispensable roles in metabolic regulation and energy balance through various mechanisms. They contribute to nutrient metabolism and energy extraction from dietary substrates, mainly complex carbohydrates that are otherwise indigestible by the host. Additionally, [27] gut microbiota produces metabolites such as short-chain fatty acids (SCFAs) and secondary bile acids, which can influence host metabolism, adiposity, and energy expenditure.

Gut microbiota interacts with the immune system and modulate inflammation, this can impact metabolic health. Dysbiosis which is characterized by [28] alterations in gut microbiota composition, has been associated with [29] obesity, insulin resistance, and metabolic syndrome, thereby highlighting the importance of a balanced and diverse gut microbiota for metabolic homeostasis.

TABLE I. HEALTHY VS. DYSBIOTIC GUT MICROBIOTA

No	Healthy Gut Microbiota	Dysbiotic Gut Microbiota
1	Diverse	Reduced diversity
2	Balanced composition	Overgrowth or undergrowth of pathogenic microbes
3	Promotes immune balance and tolerance.	causes inflammation and immune system dysfunction
4	Helps maintain gut integrity and prevents leaky gut	Leads to increased gut permeability (leaky gut)

III. Dysbiosis And Obesity

Dysbiosis is an imbalance or disruption in the composition and function of the gut microbiota, generally caused by alterations in microbial diversity, abundance, and or metabolic activity. This imbalance has been strongly associated with obesity and metabolic disorders. Individuals with obesity often show distinct alterations in gut microbiota composition compared to lean individuals [30]. Specifically, they may have reduced microbial diversity, changes in the relative abundance of specific bacterial taxa (e.g., decreased abundance of Bacteroidetes and increased abundance of Firmicutes), and alterations in the metabolic potential of the gut microbiota. Several potential mechanisms have been proposed to link dysbiosis to the development of obesity:

1. Inflammation: Dysbiosis can lead to low-grade inflammation in the gut and systemic circulation, which is implicated in the pathogenesis of obesity and metabolic syndrome. Dysbiotic microbiota may encourage the release of pro-inflammatory cytokines and activate immune cells, contributing to insulin resistance and adipose tissue dysfunction [31].

2. Energy Extraction: Dysbiotic gut microbiota may be more efficient at extracting energy from the diet, particularly from fermentable carbohydrates [32]. This enhanced energy harvest can lead to increased production of short-chain fatty acids (SCFAs) and other metabolites, which may promote adiposity and weight gain.

3. Metabolic Dysregulation: Dysbiosis can disrupt metabolic homeostasis through various pathways, including alterations in bile acid metabolism, production of bioactive metabolites, and modulation of host signaling pathways involved in energy metabolism. These disruptions can [33] contribute to insulin resistance, dyslipidemia, and other metabolic abnormalities associated with obesity

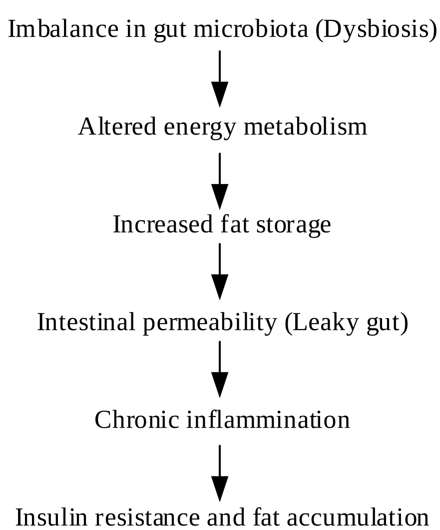

Fig. 2. Gut Microbiota Dysbiosis and Obesity Development

IV. Impact Of Nutrition On Gut Microbiota

Nutrition plays a crucial role in shaping the composition and function of the gut microbiota, with numerous dietary components exerting distinct effects on microbial communities. The Western diet, characterized by high intake of processed foods, red meat, refined sugars, and saturated fats, is connected with dysbiosis and an increased risk of obesity and metabolic disorders. This dietary pattern [34] promotes the growth of pro-inflammatory bacteria and reduces microbial diversity. In contrast, the Mediterranean diet, rich in fruits, vegetables, whole grains, legumes, fish, and olive oil, is associated with a more diverse and balanced gut microbiota composition. This dietary pattern promotes the growth of beneficial bacteria and is linked to lower rates of obesity and metabolic diseases. The dietary Components may include;

- Fiber: Dietary fiber, particularly non-digestible carbohydrates such as soluble and insoluble fibers, serves as a substrate for fermentation by gut bacteria. Fiber-rich diets [35] promote the growth of beneficial bacteria, such as Bifidobacteria and Lactobacilli, causing an increase in microbial diversity and the production of short-chain fatty acids (SCFAs), which have beneficial effects on metabolic health.

- Fat: High-fat diets, especially those rich in saturated fats, have been associated with alterations in gut microbiota composition [36], including reductions in microbial diversity and changes in the relative abundance of certain bacterial taxa. These alterations may contribute to metabolic dysfunction and obesity.

- Sugar: Excessive consumption of refined sugars and high-fructose corn syrup has been linked to dysbiosis, characterized by shifts in microbial composition and increased abundance of potentially harmful bacteria. This dysbiosis may contribute to inflammation, metabolic syndrome, and obesity risk.

Prebiotics, probiotics and dietary supplements

- Prebiotics: Prebiotics are non-digestible dietary fibers that selectively promote the growth of beneficial bacteria in the gut [37], such as Bifidobacteria and Lactobacilli. Incorporating prebiotic-rich foods, such as onions, garlic, leeks, and chicory root, into the diet can help support a healthy gut microbiota and mitigate obesity risk.

- Probiotics: Probiotics are live microorganisms that confer health benefits when consumed in adequate amounts [38]. Some probiotic strains, such as [39] Lactobacillus and Bifidobacterium species, have been shown to improve gut microbiota composition, reduce inflammation, and mitigate obesity-related metabolic dysfunction.

- Dietary Supplements: Some dietary supplements, such as polyphenols and omega-3 fatty acids, have shown to modulate gut microbiota composition and improve metabolic health [40]. These supplements may exert their effects by promoting the growth of beneficial bacteria and reducing inflammation in the gut.

V. GUT MICROBIOTA-HOST INTERACTION IN OBESITY

The complex relationship between gut microbiota and host metabolism involves bidirectional communication mechanisms that play a role in maintaining metabolic homeostasis. On one hand, the host offers nutrients and a suitable environment for the growth and maintenance of gut microbiota. On the other hand, gut microbiota contributes to host metabolism through the production of several metabolites and by modulating host signaling pathways.

Gut microbiota-derived metabolites, such as short-chain fatty acids (SCFAs), exert profound effects on host physiology and can influence the development of obesity. SCFAs, produced through the fermentation of dietary fibers by gut bacteria, serve as energy substrates for host cells and play a role in lipid metabolism [41]. SCFAs like acetate, propionate, and butyrate have been shown to regulate adipogenesis, insulin sensitivity, and energy expenditure, ultimately impacting body weight regulation. The gut microbiota also impacts appetite regulation, energy metabolism, and adipose tissue function through various mechanisms. Additionally, gut microbiota-derived metabolites can signal to distant organs, including the brain and adipose tissue, through neural, hormonal, and immune pathways, thereby influencing energy balance and adiposity [42].

VI. CLINICAL IMPLICTIONS AND THERAPEUTIC STRATEGIES

Microbiota-targeted interventions is an emerging and promising strategy for obesity management, supported by a growing body of evidence highlighting the intricate relationship between gut microbiota composition and metabolic health.

1) Studies in both animal models and humans have demonstrated links between dysbiosis and obesity, as well as improvements in metabolic parameters following interventions aimed at modulating gut microbiota composition. Fecal microbiota transplantation (FMT), in which fecal microbiota from healthy donors are transferred to individuals with dysbiosis, has shown efficacy in improving insulin sensitivity, reducing adiposity, and ameliorating metabolic dysfunction in animal models and human clinical trials.

2) Dietary interventions, such as increased fiber intake, adoption of a Mediterranean-style diet rich in fruits, vegetables, and whole grains, and supplementation with prebiotics and probiotics, have shown to promote a healthy gut microbiota composition and mitigate obesity risk.

B. Strategies for modulating gut microbiota

a) Dietary modifications, including increasing fiber intake, reducing consumption of processed foods and high-fat/sugar diets, and incorporating prebiotic-rich foods and probiotic supplements, can help promote the growth of beneficial bacteria and improve gut microbiota diversity.

b) Regular physical activity, stress management, and adequate sleep have been associated with a more diverse and balanced gut microbiota composition.

c) Developing targeted microbial therapeutics, such as engineered probiotics or microbial metabolites, that specifically modulate gut microbiota composition and function holds promise for obesity management. However, more research is needed to optimize these approaches and ensure their safety and efficacy.

C. Challenges

a) Standardization: One of the challenges in incorporating microbiota-based approaches into clinical practice is the lack of standardization in methodologies for assessing gut microbiota composition and defining dysbiosis. Establishing standardized protocols for microbiota analysis and interpretation is essential for reproducibility and comparability of research findings.

b) Personalized Medicine: Another challenge is the inherent inter-individual variability in gut microbiota composition and response to interventions. Developing personalized microbiota-based interventions tailored to individual microbiota profiles and metabolic phenotypes may enhance their efficacy.

c) Integration into Clinical Practice: Despite the promising evidence, incorporating microbiota-based approaches into routine clinical practice for obesity prevention and treatment faces barriers such as limited awareness among healthcare providers, reimbursement issues, and the need for further validation in large-scale clinical trials. Overcoming these challenges will require collaboration between researchers, clinicians, policymakers, and industry stakeholders.

d) Cultural practices of a community entail a wide range of behaviors, norms, traditions. Such practices influence various aspects of life which may include physical activity levels, dietary patterns, food preferences and cooking methods. The cultural practices of a group play a crucial role in the shaping the microbial communities residing in the gut as different dietary patterns contain diverse blends of bioactive compounds, fiber, micro and macro nutrients. These components modulate the growth and activity of gut bacteria. Traditional rich diets are associated with greater microbial diversity while western diets characterized by processed foods and saturated fats are linked to dysbiosis and inflammation.

The dietary pattern and lifestyles practiced as a culture can either reduce or increase obesity through its effects on energy balance, inflammation and metabolic regulations. A culture that promotes consumption of energy dense foods, processed foods with little or no physical activity will increase the risks of obesity.

VII. CONCLUSION

Microbiota-targeted interventions offer exciting opportunities for obesity management, but their translation into clinical practice necessitates addressing challenges related to standardization, personalized medicine, and integration into healthcare systems. Continued research efforts and interdisciplinary partnership are important for realizing the full potential of microbiota-based approaches in fighting the global obesity epidemic.

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