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Research progress on the role of β-glucan in obesity suppression through the gut microbiota

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Abstract. Globally, the prevalence of chronic illnesses is on an upward trajectory. With the number of patients suffering from hypertension, cardiovascular diseases, or obesity rising globally. world's population will be severely affected in their daily lives and work. Metabolic dysregulation caused by obesity can likely lead to a series of metabolic diseases such as hypertension, hyperlipidemia, and diabetes, while also increasing the risk of neurological disorders such as cerebral infarction or hemorrhage. numerous studies have shown that regulating the gut microbiota through the consumption of β-glucan can effectively address obesity from multiple perspectives. Therefore, researching the mechanism by which β-glucan affects chronic diseases through its action on the gut microbiota holds significant implications for the prevention and treatment of chronic diseases.

Keywords: β-glucan, Gut Microbiota, Obesity

1. Introduction

The incidence of chronic diseases worldwide is increasingly high, with the number of patients suffering from hypertension, cardiovascular diseases, or obesity rising globally. The "World Obesity Federation" predicts that by 2035, over 4 billion people will be categorized as obese or overweight, indicating that half of the world's population will be severely affected in their daily lives and work. The gut microbiota significantly contributes to the prevention and management of obesity, showcasing its beneficial impact through its evolutionary development alongside humans. This evolution has empowered it to modulate the human immune system and play a crucial role in the onset of chronic illnesses. Recent research underscores a strong link between the alteration of gut microbiota's composition and functionality and the emergence of chronic conditions such as obesity, type II diabetes, and fatty liver disease. Maintaining a balanced gut microbiota is crucial for ensuring harmony between the intestinal ecosystem and its host. An imbalance or dysbiosis in the gut microbiota is increasingly recognized as a critical element in the genesis of metabolic disorders. This imbalance leads to metabolic disturbances and encourages the growth of disease-causing microbes. Therefore, researching the impact mechanisms and modes of action of the gut microbiota on chronic diseases is of great importance for the prevention and treatment of chronic diseases [1].

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2. Literature Review

2.1. Progress in Obesity Research

The issue of obesity is escalating at an alarming rate worldwide, impacting approximately 107.7 million children and 603.7 million adults. This condition is a major contributor to mortality, with over 60% of deaths related to a high Body Mass Index (BMI). Should the current trajectory persist, projections indicate that by 2025, approximately 18% of males and 21% of females globally will be obese [2]. Moreover, obesity among adolescents is a significant health challenge, especially in affluent nations, where it affects more than 20% of the youth population. The incidence of extreme obesity in this demographic has seen a substantial increase, quadrupling since 1985. Adolescents facing obesity are at risk of several negative outcomes that affect their emotional well-being, social interactions, and physical health, including potential impacts on their growth and developmental paths. Most adolescents with obesity carry an increased risk of cardiovascular metabolic diseases and certain cancers into adulthood due to carrying excess fat [3]. In clinical trials, a formula combining weight and height is the most common and simplest estimate of body fat. In the realm of epidemiological research, the disparity in weight among individuals of the same stature is predominantly linked to body fat differences, with the Body Mass Index (BMI) serving as the primary measure for these variations. An overview of reliable body fat measurement techniques for clinical use is detailed in Table 1. Utilizing BMI to categorize levels of overweight and obesity illuminates the growth in body fat, enabling effective weight status comparisons both within groups and across different populations. Such comparisons are crucial for identifying at-risk demographics for health complications and premature death. Moreover, understanding BMI classifications aids in prioritizing health interventions on an individual and community basis and in gauging the success of these measures. It's important to recognize that due to differences in body proportions, BMI may not correspond to the same degree of obesity across different populations [3]. BMI is a crucial indicator for determining overweight and obesity.

Table 1. Defining Obesity

Method	Definition	Advantages/limitations
BMI	Weight in kilograms divided by square of the height in metres	BMl correlated strongly with densitometry measurements of fat mass; main limitation is that it does not distinguish fat mass from lean mass
Waist Circumference	Measured (in centimetres) at midpoint between lower border of ribs and upper border of the pelvis	Waist circumference and waist-to-hip ratio provide measures for assessing upper body fat deposition; neither provide precise estimates of intra-abdominal (visceral) fat
Skinfold Thickness	Measurement of skinfold thickness (in centimetres) with callipers provides a more precise assessment if taken at multiple sites	Measurements are subject to considerable variation between observers, require accurate callipers and do not provide any information on abdominal and intramuscular fat
Bioimpedance	Based on the principle that lean mass conducts current better than fat mass because it is primarily an electrolyte solution; measurement of resistance to a weak current (impedance) applied across extremities provides an estimate of body fat using an empirically derived equation	Devices are simple and practical but neither measure fat nor predict biological outcomes more accurately than simpler anthropometric measurements

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2.2. The Biological Activity of β-glucan and Its Impact on the Gut Microbiota

β-Glucan, recognized as a valuable soluble dietary fiber, is derived from a diverse array of sources, including but not limited to, oats, barley, certain seaweeds, grains, as well as mushrooms and yeasts. Beyond these, it's also found within a range of bacteria and fungal species such as Pneumocystis carinii, Cryptococcus neoformans, Candida albicans, Aspergillus fumigatus, Saccharomyces cerevisiae, and Histoplasma capsulatum. Structurally, β-glucan comprises a complex chain of over 250,000 D-glucose units, intricately linked by β-glycosidic bonds, highlighting its natural polysaccharide identity. The structure of β-glucan varies depending on its source; for instance, the β-glucan found in mushrooms has short β (1,6) branches off a β (1,3) main chain, whereas the β-glucan from oats and barley consists of linear β (1,4) bonds with shorter β (1,3) structural chains (Figure.1) [4]. Foods rich in β-glucan are considered important candidates for healthy diets due to their multiple biological activities.

The gastrointestinal tract of higher animals harbors a large community of microorganisms (gut microbiota), including bacteria, archaea, viruses, and fungi. Scientists have discovered that the gut microbiota of higher animals is associated with various health-promoting activities. Modifications within the gut microbiota have profound impacts on both the physiological and functional states of the host organism. Foods containing prebiotics, aimed at bolstering gut microbiota populations, include high-fiber selections such as oats, mushrooms, seaweeds, and barley. Among these, β-glucan is identified as a pivotal prebiotic ingredient. Crucial for diabetes control are the stabilization of blood glucose, management of lipid levels, and regulation of blood pressure. Studies have demonstrated that dietary β-glucan intake effectively diminishes the challenges associated with diabetes, including its complications. Similarly, results suggest that Ganoderma lucidum (Reishi mushroom), rich in β-glucan, is used as an adjunct therapy for cancer treatment. Table 2 presents the effects of β-glucan from different sources on the gut microbiota and the health benefits generated [4].

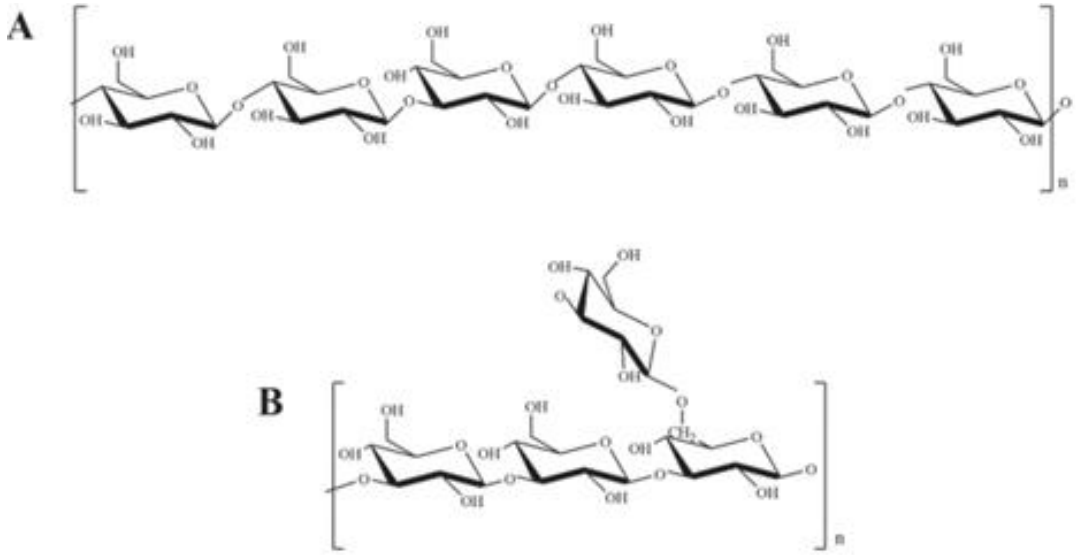

Figure 1. The structures of β-glucans [1]. (A) Cereals β-glucan and (b) Baker's yeast β-glucan

Table 2. Types of β-glucans, sources, regulation of gut microbiota and health benefits.

β-Glucans	Sources	Action on gut microbiota	Health benefits
Glomerellan	Glomerella cingulata	Glomerellan stimulates the immune system through microbiota.	Immune stimulant and anticancer property

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Table 2. (continued)

LNT (Lentinan)	Lentinus(Lentinula edode)	Upon INT feeding, microbiota exhibit distinctly different space distribution. LNT reduced the diversity and evenness of gut microbiota	Synergistic action against breast cancer. Effective against colorectal cancer.
PSG(Polysaccharide Ganoderma)	Lucidum and Ganoderma atrum	Exact action on gut microbiota is not yetelucidated well	Exerts antitumor activity by activating mitochondria-mediated apoptotic pathway and boosting the immun systeml
Oats and barley beta glucans	Oats and barley	β-Glucans reduced the P-Cresyl Sulfate, LDL and total cholesterol levels through gut microbiota taxonomic composition modulation and changes in its metabolism.	Hypocholesterolemic activity
SR (Scleroglucan)	Sclerotium rolfsii or S. glucanicum	Exact role in microbiota is not elucidated well	Effective against colorectal cancer
PGG (betafectin)	Saccharomyces cerevisiae	The immunomodulation activity of PGG is through altering the microbiota population in gut	Immunomodulator property
Zymocel	Saccharomyces cerevisiae	No alterations on microbiota have been seen.	Shows in vivo immunopharmacological activity in mice
SPG (Sonifilan/schizophyllan)	Schizophyllum commune	The SCFAs produced from the action of microbiota on these prebiotics have the ability to prevent colon cancer.	Acts as a biological response modifer for mouse tumor systems. Protects against colon cancer
GRN (grifolan)	Grifola fondosa (maitake mushroom)	Butyrate is produced from this prebiotics via microbiota have many protective functions, such as differentiation regulator of mucosal gene expression and apoptosis	Grifolan from Grifola fondosa showed high antitumor activities

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2.3. The Gut Microbiota and Obesity

During the 1980s, investigations identified a correlation between gut microbiota and obesity across human and rat populations, paving the way for further research. By the 1990s, advancements in molecular biology, particularly the use of 16S rRNA gene-based techniques, allowed for deeper insights into this association. The process by which gut bacteria ferment non-digestible polysaccharides to produce short-chain fatty acids (SCFAs) such as butyrate, acetate, and propionate, contributes significantly to the host's energy intake, ranging from 80 to 200 kcal/day. These SCFAs are essential for the host's energy supply and are absorbed by several organs. It has been observed that a reduction in dietary carbohydrates is linked to a decrease in both butyrate levels and the bacteria that produce it in obese individuals' stool samples. Further research corroborates that a low-fiber diet leads to a reduction in fecal butyrate, total SCFAs, and Bifidobacteria counts in obese patients. Thus, dietary fibers have a profound impact on the gut microbiota's composition and, consequently, on the host's overall health [5].

Metabolic dysregulation caused by obesity can likely lead to a series of metabolic diseases such as hypertension, hyperlipidemia, and diabetes, while also increasing the risk of neurological disorders such as cerebral infarction or hemorrhage. Over the past few decades, numerous scientists have found correlations between the gut microbiota, β-glucan, and the prevention and treatment of obesity-related diseases [1]. The gut microbiota has reached a mutualistic equilibrium with the human body over many years of coexistence. It participates in the host's energy metabolism, immune response, and biological antagonism. As a complex and dynamic system, it maintains the physiological balance of the body through long-term co-evolution with the organism and interaction with the environment [6]. In recent years, researchers have found that a wide range of diseases can be influenced by various types and degrees of changes in the gut microbiota, and now it has been discovered that regulating the gut microbiota with β-glucan can effectively address obesity. β-glucan promotes the production of butyrate by the human gut microbiota. If there is an enzyme in the intestine capable of degrading indigestible polysaccharides, then the number of fermentation end products (acetate and butyrate) in the feces of obese patients would increase, suggesting that the cause of obesity could be due to an increased energy intake. Some researchers have also found through mouse experiments that changes in the microbial population size and distribution of the gut microbiota are related to obesity. The gut microbiota, by engaging in various metabolic activities of the host, including the breakdown of diet, transformation of conjugated bile acids, and synthesis of certain vitamins and fermentation of indigestible dietary fibers to obtain energy from food, can also impact the body's metabolic activities [7].

3. The Mechanism of Anti-Obesity Action of β-glucan Through the Regulation of Gut Microbiota

3.1. Regulation of Gut Microbiota Composition by β-glucan

β-Glucan, a dietary polysaccharide extracted from grains, mushrooms, fungi, and bacteria, has been identified to play a crucial role in the modulation of gut microbiota, offering a therapeutic angle against obesity [7]. Research indicates a direct correlation between obesity and gut dysbiosis. Experimental data from obese mouse models show that β-glucan supplementation results in an altered gut microbiome, characterized by an increase in Bacteroidetes and anaerobes, and a decrease in lactobacilli and Enterobacteriaceae. Such dietary interventions lead to an augmented presence of Bifidobacteria and lactobacilli, escalating the production of short-chain fatty acids (SCFAs). These metabolic by-products activate immune responses, curbing inflammation linked to obesity [8]. Further observations reveal that β-glucan's impact on the gut flora—promoting beneficial bacteria while suppressing detrimental ones—is more pronounced with β-glucans of lower molecular weight, attributed to their superior fermentation and degradation capabilities in the gut.

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3.2. The Fermentation Products of β-glucan Suppress Obesity

Through the intestinal microbiota's fermentation of β-glucan, short-chain fatty acids (SCFAs) are produced, which are instrumental in triggering a variety of gut hormones. These hormones are pivotal in enhancing carbohydrate digestion, lowering blood sugar, managing appetite, and modifying both the composition and metabolic activity of the gut microbiota, thus aiding in obesity reduction [9]. Experiments on live models have illustrated that β-glucan, particularly from oats, acts as a prebiotic that reaches the large intestine for fermentation into SCFAs. This is mirrored in vitro studies where oat β-glucan, used as a fermentation base with animal stools, similarly boosts SCFA levels. Research by Suzuki and others further confirms that high β-glucan barley consumption leads to increased SCFA concentrations in the cecum of obese mice, highlighting the prebiotic efficacy of this water-soluble dietary fiber, β-glucan. The acetate produced through fermentation in the large intestine is not only an energy source for the liver and peripheral tissues but also a molecular signal for gluconeogenesis and lipogenesis pathways; the propionate produced inhibits fatty acid synthase, thereby helping to reduce blood lipid levels; the butyrate produced provides energy for the intestinal epithelium, conducive to maintaining the integrity of the intestinal mucosa. The intestinal mucosa contains endocrine L-cells that can secrete a variety of peptides, among which GLP-1 and PYY play important roles in regulating food intake and promoting pancreatic function [8]. Research has also confirmed that SCFAs can regulate the expression of the precursor of glucagon-like peptide, which is related to regulating food intake, fat accumulation, and pancreatic function. The fermentation product butyrate can also inhibit inflammatory responses, playing a significant role in apoptosis, cell proliferation, and reducing the risk of colon cancer [10].

3.3. Inhibition of Fat Formation by β-glucan

Managing fat synthesis is a pivotal strategy in combating obesity. It's been documented that subjects consuming β-glucan from barley over six weeks experienced reductions in body weight, waist dimensions, and visceral fat. β-Glucan facilitates this by boosting enzymes responsible for fat metabolism while inhibiting fat-storing enzymes, thereby limiting fat accumulation [11]. Evidence supports that β-glucan's consumption significantly affects fat storage and lipid metabolism regulation, presenting a preventive measure against fat deposition [12]. In research with obese mice administered soluble and insoluble β-glucan, notable improvements were seen in body weight, lipid levels, and other health indicators after six weeks, highlighting β-glucan's potential in improving obesity-related metrics [13,14]. Additionally, a study involving Japanese participants with visceral fat-type obesity demonstrated that a diet rich in β-glucan from barley over 12 weeks effectively reduced body weight, visceral fat, BMI, and waist size, offering a viable option for managing visceral fat-type obesity [15].

4. Conclusion

In summary, numerous studies have shown that regulating the gut microbiota through the consumption of β-glucan can effectively address obesity from multiple perspectives. Firstly, β-glucan can alter the quantity of different microbial populations within the intestine, promoting the growth and activity of beneficial bacteria, thereby modulating the composition of the gut microbiota. Secondly, the fermentation of β-glucan by the gut microbiota produces SCFA products. SCFAs can activate intestinal hormones, effectively influencing the composition of gut microbiota and carbohydrate metabolism, thus reducing the incidence of obesity. Lastly, β-glucan can effectively inhibit the formation of fat. It can reduce the accumulation of white adipose tissue and enhance the activity of certain beneficial enzymes while decreasing the activity of some lipases and proteases, thereby reducing fat accumulation. Overall, researching the mechanism by which β-glucan affects chronic diseases through its action on the gut microbiota holds significant implications for the prevention and treatment of chronic diseases.

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