ABRAN ASSOCIAÇÃO BRASILEIRA DE NUTROLOGIA
International Journal of Nutrology
(Official Journal of the ABRAN - Brazilian Association of Nutrology)

REVIEW ARTICLE

DOI: 10.54448/ijn26316

Impact of the dietary modification on GM in metabolic syndrome and obesity: a narrative review

Hemavathi Raghupathi[1,*]; Padmapriya Deenadayalan[2]; Sukanya[3]; Vijayalakshmi Ravi[4]; Parimala Lakshmanan[4]

[1] Saveetha Institute of Medical and Technical Sciences (SIMATS). Saveetha College of Nursing. Department of obstetrics and Gynecological Nursing, Chennai, Tamil Nadu, India.
[2] Saveetha Institute of Medical and Technical Sciences (SIMATS). Saveetha College of Nursing. Department of obstetrics and Gynecological Nursing, Chennai, Tamil Nadu, India.
[3] RR College of Nursing. Department of obstetrics and Gynecological Nursing, Chikkabanavara, Bangalore, Karnataka, India.
[4] Saveetha Institute of Medical and Technical Sciences (SIMATS). Saveetha College of Nursing, Chennai, Tamil Nadu, India.

*Corresponding author: Hemavathi Raghupathi.
Saveetha Institute of Medical and Technical Sciences (SIMATS). Saveetha College of Nursing. Department of obstetrics and Gynecological Nursing, Chennai, Tamil Nadu, India.
E-mail: hemavathi24@yahoo.com
DOI: https://doi.org/10.54448/ijn26316
Received: 04-11-2026; Revised: 07-22-2026; Accepted: 07-24-2026; Published: 08-03-2026; IJN-id: e26316

Editor: Dr. Idiberto José Zotarelli-Filho, MSc, Ph.D., Post-Doctoral.

Abstract

Introduction: Obesity and metabolic syndrome (MetS) are emerging public health problems globally and risk factors for cardiovascular diseases, nonalcoholic fatty liver disease and type 2 diabetes mellitus. **Objective:** The purpose of this review was to investigate the relation between GM and dietary modification in obesity and the metabolic syndrome, and the role of dietary modification in obesity and metabolic syndrome prevention and treatment. **Methods:** A narrative review of published data was performed, using peer-reviewed studies that included "gut microbiota," "dietary pattern," "obesity" and/or "metabolic syndrome," "microbiota-targeted interventions. Appropriate findings were aggregated to analyse the interface amongst sustenance, gut microbial structure and metabolic well-being. **Results**: GM plays a key role in digestion, synthesis of short chain fatty acids, active role in immune system, vitamin synthesis, and energy homeostasis. Dysbiosis, defined by a decrease in the diversity of microorganisms and a change in the composition of the community, is linked to obesity and metabolic syndrome in various ways such as increase in energy harvest, metabolic endotoxemia, chronic inflammation, impairment of the barrier function, and insulin resistance. A pro-dysbiotic diet in the West has been shown to cause imbalances in the microbial community and dysmetabolism, while consumption of high fiber, plant-rich diets with prebiotics and some low carbohydrate diets have shown to be beneficial for the microbial population and dysmetabolism. New treatment strategies include probiotics, gut microbiome transfer, bariatric surgery and precision nutrition, which appear to be useful in the rebalancing of the microbiota. **Conclusion:** Modulating gut microbes with foodstuffs is a powerful, non-drug approach to enhancing metabolic and nutritional outcomes and could help decrease the burden of obesity and related comorbidities.

Keywords: Dietary modulation; Mediterranean diet; Short-chain fatty acids; Dysbiosis; Precision nutrition; Probiotics; Prebiotics.

Introduction

Obesity and metabolic syndrome (MetS) are inseparably associated conditions, which together form a worldwide epidemic with severe consequences for morbidity, mortality, and the cost of health services **[1,2]**. The metabolic syndrome is a group of metabolic disorders that consist of three or more of five metabolic abnormalities, including central obesity, high concentration of fasting blood glucose, hypertension, high serum triglycerides, and low serum high-density lipoprotein (HDL) cholesterol. These risk factors are likely to be co-occurring and further increase the risk associated with cardiovascular disease (CVD) and diabetes **[3-5]**.

Current strategies for obesity and MetS, such as caloric restriction, augmentation of physical activity, use of pharmacotherapy, and bariatric surgery, have shown limited long-term success and can have detrimental side effects **[6 -8]**. The gut microbiota (GM) is made of bacteria, viruses, and fungi, which are important for the development of essential functions such as the immune system, vitamin synthesis, and bioactive metabolite production **[9,10]**. Dysbiosis of this microbial community has been observed to be consistently linked via multiple mechanisms such as altered energy extraction, increased intestinal permeability, systemic low-grade inflammation, and impaired insulin signaling **[11-13]**.

Dietary macro and micronutrients have distinct effects on microbial community composition, bile acid synthesis, and key metabolite levels. Hence, it is crucial to understand how certain dietary patterns and components influence GM relation to obesity and MetS to develop evidence-based nutritional interventions **[14-16]**.

The purpose of this review was to investigate the relation between GM and dietary modification in obesity and the metabolic syndrome, and the role of dietary modification in obesity and metabolic syndrome prevention and treatment.

Methods

A narrative literature review was performed, to explore the link between dietary changes, gut microbiome, obesity and metabolic syndrome. Suitable articles were gathered by searching electronic databases of PubMed, Scopus, Web of Science and google scholar. Only peer-reviewed studies in English on gut microbiota, dietary patterns, obesity, metabolic syndrome, and interventions for targeting the microbiota were included. The eligible studies were discussed and the findings analyzed, synthesized, and organized into the following themes: gut microbiota composition and function, dysbiosis in obesity and metabolic syndrome, diet and gut microbiota, metabolites produced by the microbiota, therapeutic approaches, and comorbidities. These findings were critically analysed and current evidence around the potential for dietary modulation on gut microbiota, and subsequent metabolic health summarized.

Results

The intestinal microbiota: composition, diversity and core functions

The Human GM- Overview

The human gut microbiota (GM) is a very diverse and complex ecosystem composed of roughly 1013 to 1014 microorganisms. Four of the phyla are predominant and make up the majority of the microbial population: bacteria and proteobacteria. Dietary intake is the primary influence on GM composition, accounting for nearly 60% of the overall differences and highlighting the importance of diet in the shaping of microbial communities **[17,18]**.

The GM renders several essential physiological functions, such as digestion, fermentation of food fibers that produce short-chain fatty acids (SCFAs), vitamin synthesis, metabolism of bile acids, and shaping growth and immunity. Moreover, it is involved in the formation of bioactive compounds that act on the nervous system, thereby influencing the gut–brain interaction. Of great relevance is the fact that the GM also seems to play a major role in the regulation of energy homeostasis; this role refers to the mechanisms of fat storage and energy extraction from the food consumed **[19]**.

Factors impacting the composition of the Intestinal Microbiota

Only 5-10% of the differences in bacterial taxonomy are due to genetic differences; most are due to environmental factors, mainly diet. The foundations of the microbiota are set early in life, with mode of delivery, breastfeeding, and maternal diet during pregnancy being important determinants of their metabolic health implications **[20]**.

Another important factor changing GM diversity is antibiotic consumption, as microbiota community structure can change after even brief antibiotic courses. The microbiota is regulated by a multitude of elements, not only food. These factors include smoking, physical activity, stress, and sleep hygiene, among others **[21]**.

GM Dysbiosis in Obesity and Metabolic Syndrome

Obesity is associated with dysbiosis in gut microbiota, characterized by a decrease in microbial variety and alterations in microbial composition. An imbalance in the Firmicutes-to-Bacteroidetes ratio in obese people has been reported and could lead to greater harvest of dietary energy and weight gain. The essential function of GM in obesity is underlined by these microbial alterations, which can contribute to insulin resistance and metabolic dysfunction as well as impair gut barrier function and promote chronic low-grade inflammation **[21,22]**. Obesity is linked with changes in the composition of microbes and reduced diversity, as well as an increase of pathogenic taxa. Summarized characteristic features of GM dysbiosis are displayed in Figure 1.

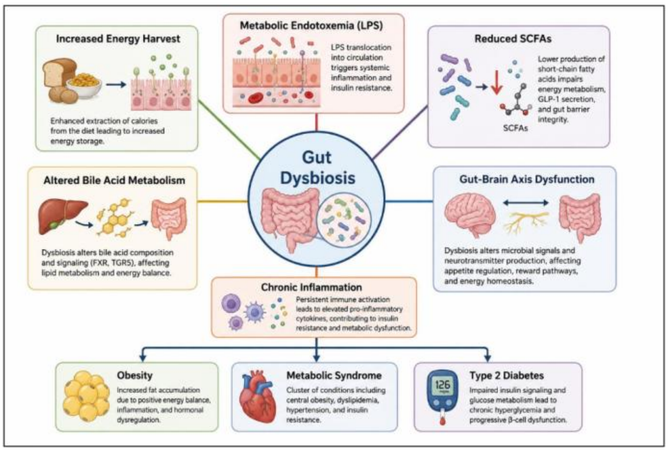

Figure 1. Characterized by gut microbiota dysbiosis. Source: Own authorship.

Dietary habits and their impacts

The western diet

Adopting a Western diet (high utilization of refined carbohydrates, saturated fat, trans fat, red and processed meats, and ultra-processed food with low dietary fiber, fruits, and vegetables) is strongly linked to GM dysbiosis and obesity and MetS. A high-fat diet (HFD) causes an abrupt and significant shift in GM composition with an increase in Proteobacteria and Desulfovibrio and a decrease in *Akkermansia muciniphila* and Bifidobacterium as well as a decrease in microbial diversity **[23,24]**.

Excessive amounts of refined carbohydrates and added sugars also affect gut bacteria by increasing the populations of disease-causing bacteria while decreasing the populations of fiber-fermenting and SCFA-producing gut bacteria. The Western diet is also known to decrease the amount of butyrate and other SCFAs, which in turn can lead to a decrease in intestinal barrier function and therefore metabolic endotoxemia. Adults with a Western diet have an increased risk for obesity and other conditions such as cardiovascular disease, MetS, and NAFLD **[25]**.

High Fiber Diets and Prebiotics

Dietary fiber and prebiotics are important modulators of GM and are important to prevent obesity and metabolic syndrome. Fiber strengthens Bifidobacterium, Lactobacillus, Roseburia, and *Faecalibacterium prausnitzii* which helps regulate appetite. Studies have also shown a relationship between a high-fiber diet and increased satiety, lower intake of energy, better insulin sensitivity, and weight management, which emphasizes the potential of fiber in preventing obesity and metabolic syndrome **[26,27]**.

Ketogenic Diet

A ketogenic diet is an excess-fat and low-carbohydrate diet that causes a metabolic state of ketosis, and it is linked with weight loss and glycemic control. KD has been shown to affect the gut microbiota by increasing beneficial microorganisms like *Akkermansia muciniphila* and Lactobacillus species and altering gut–brain signals and metabolic processes **[28]**.

Plant-Based and Vegan/Veggie Diets

Individuals who follow plant-based diets have significantly higher gut microbial diversity and an abundance of beneficial bacteria. They have a rich fiber content and encourage the production of SCFA, which helps maintain metabolic health; at the same time, the intake of animal products is low, which helps reduce harmful metabolites. These benefits vary by the quality and variety of plant foods that are eaten **[29]**.

Less Carbohydrate and Excess-Fat Diets

Low-fat, excess-carbohydrate (LCHF) diets have been documented to enhance insulin reactivity, body weight, and glycemic control and thus may be beneficial for obesity, metabolic dysfunction, and type 2 diabetes. But too much of the wrong kinds of fats can negatively affect gut microbiota by lowering microbial diversity and increasing the number of potentially pathogenic bacteria in the gut. It matters which type of dietary fat you consume, as omega-3 fatty acids tend to promote a healthier gut microbiota, while saturated fats tend to be more linked to dysbiosis and negative metabolic effects **[30-35]**.

Gut microbiota-derived metabolites and metabolic health

Bile acids

Bile acids contain derivatives of cholesterol that play a role in assimilating lipid and regulating metabolism. Primary bile acids are transformed to secondary ones through gut microbiota, both of which activate FXR and TGR5, effecting glucose, lipid and energy balance.

However, the process can be disturbed by dysbiosis which is linked with metabolic syndrome, type 2 diabetes and with NAFLD. These interactions suggest that bile acid–microbiota pathways could be a therapeutic target for cardiometabolic diseases **[36-39]**.

Therapeutics interventions for gut microbiota

Gut microbiome transfer (GMT)

The process of GMT involves transferring the microbiota of a donor's healthy gut to a patient's, with the aim of rebalancing the microbiota. Preliminary studies indicate that GMT from lean donors can enhance insulin sensitivity and boost the levels of guardedly health-promoting bacteria that produce butyrate in people with obesity and metabolic syndrome. But its weight loss and anti-inflammatory properties have been inconsistent, and more study should be conducted to determine the best donor, preparation and application procedures **[40,41]**.

Bariatric Surgery and Gut Microbiota

Bariatric surgeries are successful interventions for severe obesity, and they trigger huge changes in the structure of gut microbiota. These include an increased population of beneficial bacteria, e.g. *Akkermansia muciniphila*, and synthesis of short-chain fatty acids leading towards beneficial metabolic effects. The alterations of microbiota species composition that have been reported after bariatric surgery may explain the greater impact of this surgery on weight loss and metabolic health as compared to classic lifestyle changes as a weight loss approach **[42]**.

Precision Nutrition and Personalized Microbiota Based Interventions

Precision nutrition seeks to ensure that dietary advice is personalized on the basis of the composition of an individual's gut microbiome, his or her DNA, and metabolic features. Through improvements in microbiome sequencing technologies and the utilization of bioinformatics, personalized diet, probiotics, and prebiotics can be developed that aim to influence the growth of beneficial microbes and boost outcomes in metabolic health. This new method may be used to prevent and treat obesity and metabolic syndrome, but it needs to be standardized and validated clinically **[43]**. Precision nutrition is an exciting future trajectory for microbiome research, combining interventions with microbiome, genetic, metabolic and lifestyle information to offer personalized nutrition advice (Figure 2).

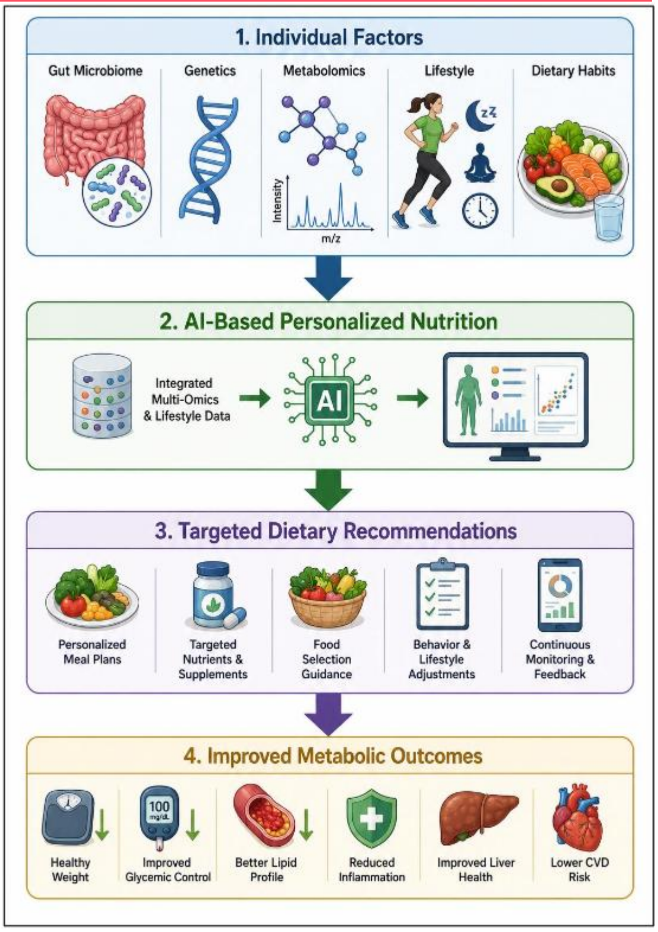

Figure 2. The precision nutrition framework. Source: Own authorship.

Intestinal microbiota and comorbidities

Type 2 diabetes mellitus

GM is central in the pathogenesis of T2DM and dysbiosis leads to the disruption of insulin sensitivity, chronic inflammation and alteration of glucose metabolism. Dietary therapies like probiotics, a high-fiber diet, and the Mediterranean diet have enhanced insulin sensitivity and glycemic management in people with type 2 diabetes and prediabetes **[44,45]**.

Cardiovascular disease

GM dysbiosis is associated to cardiovascular risk via various mechanisms such as an increase in TMAO production, an imbalance in bile acid metabolism, systemic inflammation and endothelial function. Studies suggests that the GM influences atherosclerosis risk factors including insulin resistance, dyslipidaemia, and inflammation. Furthermore, chemicals generated by gut microorganisms have revealed novel disease pathways. There are dietetic interventions that favorably modulate GM such as high fiber and Mediterranean diet, which are known to decrease cardiovascular risk **[46]**.

Polycystic Ovary Syndrome and Endocrine Disorders

Dysbiosis in the GM causes polycystic ovarian syndrome (PCOS) in women who are overweight or have a high-fat diet. This leads to an overproduction of androgens by the ovaries, an overactive immune system, inflammation, and insulin resistance in the follicles. Some probiotic strains have been shown to be beneficial in clinical studies in diabetes and various metabolic disorders such as obesity and PCOS. Re-establishment of bacterial microbiota with fecal transplant has been suggested to improve or prevent pathologies like diabetes mellitus, MetS, and PCOS **[47,48]**.

Discussion

The present review aims at emphasizing the importance of GM in obesity and metabolic syndrome pathogenesis and prevention. What these microorganisms in the human gut are able to do are vital functions such as digestion, production of short chain fatty acids (SCFAs), vitamin synthesis, immune regulation and energy homeostasis functions. Dietary intake is known to be the major factor influencing the variation amongst different individuals in their GM diversity and constitutes a significant part of the interindividual variability **[17-19]**.

GM dysbiosis is well known to be associated with obesity and metabolic syndrome. Decreased microbial diversity, microbial changes and imbalance in Bacteroides/Firmicutes ratio has been associated with the increase in the energy harvest, weight gain, insulin resistance, impaired gut barrier function and chronic low-grade inflammation **[21,22]**. These findings corroborate the idea that dysbiosis plays an important role in metabolic dysfunction and the risk of cardiometabolic conditions.

Food and feeding habits can have an enormous impact on the gut microbiota. High consumption of saturated fats, refined carbs, or ultra processed food leads to dysbiosis, increased intestinal permeability, endotoxemia and systemic inflammation which in turn increases risk of obesity and metabolic syndrome **[24,25]**. On the other hand, high fiber, plant-based and prebiotic-rich food contributes to the growth of beneficial bacteria, promoting the production of SCFA, improvement in insulin sensitivity and weight management **[26-29]**.

Recent treatment techniques like probiotics, transfer of the microbiome, bariatric surgery, and precision nutrition have shown promise in reconstitution of microbial balance and in better metabolic outcomes **[40-44]**. In addition, modulation of Intestinal Microbiota decreases the risk of obesity-related comorbidities such as type 2 diabetes mellitus, cardiovascular disease and polycystic ovary syndrome **[45-48]**. Altogether, these data indicate that a modulation of the GM by diet is a sustainable and promising way of preventing and managing obesity and metabolic syndrome.

Limitations

This narrative review is limited by its non-systematic methodology, which may introduce selection bias. The included studies vary in design, population, dietary interventions, and microbiota assessment methods, limiting direct comparisons and the generalizability of findings. Additionally, the review does not provide a quantitative synthesis or meta-analysis of the available evidence.

Future directions

Finally, dietary modulation of gut microbes in obesity and metabolic syndrome is an emerging and very active field that offers numerous possibilities for research and applications. One of the key points to look ahead is precision nutrition approaches, incorporating microbiome, genetic, metabolic, lifestyle, and dietary data. These customized approaches could enable individualized dietary interventions that could better shift the gut microbiome composition toward a healthier metabolic profile in obese people and those with metabolic syndrome.

More research is required to examine the therapeutic potential of next generation strains of probiotics like *A. muciniphila* and *F. prausnitzii*, two species of bacteria that have been seen to have a positive effect on metabolism. Other emerging application areas for FMT include optimization of application protocols and the development of microbiota-targeted therapies for obesity and metabolic syndrome. In the near future, we can expect to see that the new frontier of clinical nutrition, namely microbiome science, will be a big part in preventing and managing metabolic disorders.

Conclusion

The GM plays a vital role in metabolic health and is closely linked to obesity and metabolic syndrome. Dysbiosis contributes to increased energy harvest, chronic inflammation, impaired gut barrier function, insulin resistance, and metabolic dysfunction. Diet strongly influences gut microbiota composition, with Western diets promoting dysbiosis, while high-fiber, plant-based, and prebiotic-rich diets support beneficial microorganisms and improve metabolic health.

Emerging interventions, including probiotics, gut microbiome transfer, bariatric surgery, and precision nutrition, show promise in restoring microbial balance. Overall, dietary modulation of the GM is a practical strategy for preventing and managing obesity, metabolic syndrome, and related metabolic disorders.

CRediT

Author contributions: Conceptualization; Data curation; Formal Analysis; Investigation; Methodology; Project administration; Writing - original draft; Writing-review & editing- All authors.

Acknowledgment

Not applicable.

Ethical Approval

Not applicable.

Informed Consent

Not applicable.

Funding

Not applicable.

Data Sharing Statement

A statement specifying where the underlying data, materials, or code can be accessed, or confirmation that it is available upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

Similarity Check

It was applied by Ithenticate®.

Application of Artificial Intelligence (AI)

Not applicable.

Peer Review Process

It was performed.

References

1. Pillai SS, Gagnon CA, Foster C, Ashraf AP. Exploring the gut microbiota: key insights into its role in obesity, metabolic syndrome, and type 2 diabetes. J Clin Endocrinol Metab. 2024;109(11):2709-2719. doi:10.1210/clinem/dgae499
2. Busch CBE, Bergman J, Nieuwdorp M, van Baar ACG. Role of the intestine and its Intestinal Microbiotain metabolic syndrome and obesity. Am J Gastroenterol. 2024;119(6):1038-1046. doi:10.14309/AJG.0000000000002730
3. Chaplin A, Carpéné C, Mercader J. Resveratrol, metabolic syndrome, and gut microbiota. Nutrients. 2018;10(11):1651. doi:10.3390/nu10111651
4. Callender C, Attaye I, Nieuwdorp M. The interaction between the gut microbiome and bile acids in cardiometabolic diseases. Metabolites. 2022;12(1):65. doi:10.3390/metabo12010065
5. Nguyễn TTB, Jin Y, Chung H, Hong S. Pharmabiotics as an emerging medication for metabolic syndrome and its related diseases. Molecules. 2017;22(10):1795. doi:10.3390/molecules22101795
6. Ahmad J, Khan I, Zengin G, Mahomoodally MF. The gut microbiome in the fight against obesity: the potential of dietary factors. FASEB J. 2023;37(11). doi:10.1096/fj.202300864RR
7. Kamal FD, Dagar M, Reza T, et al. Beyond diet and exercise: the impact of Intestinal Microbiotaon control of obesity. Cureus. 2023. doi:10.7759/cureus.49339
8. Martinez K, Pierre JF, Chang EB. The gut microbiota. Gastroenterol Clin North Am. 2016;45(4):601-614. doi:10.1016/j.gtc.2016.07.001
9. Comess JE, Abad-Jorge A. Introduction to the gut microbiome and its impact on health and disease. Top Clin Nutr. 2023;38(3):183-195. doi:10.1097/TIN.0000000000000324
10. Santangelo A, Corsello A, Spolidoro GCI, et al. The influence of ketogenic diet on gut microbiota: potential benefits, risks and indications. Nutrients. 2023;15(17):3680. doi:10.3390/nu15173680
11. Chae YR, Lee YR, Kim Y, Park H. Diet-induced gut dysbiosis and leaky gut syndrome. J Microbiol Biotechnol. 2024;34(4):747-756. doi:10.4014/jmb.2312.12031
12. Enache RM, Profir M, Roşu OA, Creţoiu SM, Gaşpar B. The role of Intestinal Microbiotain the onset and progression of obesity and associated comorbidities. Int J Mol Sci. 2024;25(22):12321. doi:10.3390/ijms252212321
13. Wei Y, Zheng K, Wang Y. Gut microbiota-derived metabolites as key mucosal barrier modulators

in obesity. World J Gastroenterol. 2021;27(33):5555-5565. doi:10.3748/wjg.v27.i33.5555

14. Attaye I, Pinto-Sietsma SJ, Herrema H, Nieuwdorp M. A crucial role for diet in the relationship between Intestinal Microbiotaand cardiometabolic disease. Annu Rev Med. 2020;71(1):149-161. doi:10.1146/annurev-med-062218-023720
15. Telle-Hansen VH, Holven KB, Ulven SM. Impact of a healthy dietary pattern on Intestinal Microbiotaand systemic inflammation in humans. Nutrients. 2018;10(11):1783. doi:10.3390/nu10111783
16. Ilyés T, Silaghi C, Crăciun A. Diet-related changes of short-chain fatty acids in blood and feces in obesity and metabolic syndrome. Biology (Basel). 2022;11(11):1556. doi:10.3390/biology11111556
17. Puljiz Z, Kumrić M, Vrdoljak J, et al. Obesity, gut microbiota, and metabolome: from pathophysiology to nutritional interventions. Nutrients. 2023;15(10):2236. doi:10.3390/nu15102236
18. Abeltino A, Hatem D, Serantoni C, et al. Unraveling the gut microbiota: implications for precision nutrition and personalized medicine. Nutrients. 2024;16(22):3806. doi:10.3390/nu16223806
19. Barber TM, Kabisch S, Pfeiffer A, Weickert MO. The effects of the Mediterranean diet on health and gut microbiota. Nutrients. 2023;15(9):2150. doi:10.3390/nu15092150
20. Gohir W, Ratcliffe EM, Sloboda DM. Of the bugs that shape us: maternal obesity, the gut microbiome, and long-term disease risk. Pediatr Res. 2015;77(1-2):196-204. doi:10.1038/pr.2014.169
21. Clemente-Suárez VJ, Redondo-Flórez L, Rubio-Zarapuz A, Martín-Rodríguez A, Tornero-Aguilera JF. Microbiota implications in endocrine-related diseases: from development to novel therapeutic approaches. Biomedicines. 2024;12(1):221. doi:10.3390/biomedicines12010221
22. Khan MJ, Gerasimidis K, Edwards CA, Shaikh MG. Role of Intestinal Microbiotain the Aetiology of Obesity: Proposed Mechanisms and Review of the Literature. J Obes. 2016;2016:7353642. doi:10.1155/2016/7353642
23. Pandit S, Meganathan P, Vedagiri H. Harmonizing Intestinal Microbiotadysbiosis: unveiling the influence of diet and lifestyle interventions. Metab Open. 2025;27:100384. doi:10.1016/j.metop.2025.100384
24. Org E, Mehrabian M, Lusis AJ. Unraveling the environmental and genetic interactions in atherosclerosis: central role of the gut microbiota. Atherosclerosis. 2015;241(2):387-399. doi:10.1016/j.atherosclerosis.2015.05.035
25. Xu Y, Wang N, Tan H, Li S, Zhang C, Feng Y. Function of Akkermansia muciniphila in obesity: interactions with lipid metabolism, immune response and gut systems. Front Microbiol. 2020;11:219. doi:10.3389/fmicb.2020.00219
26. Castro-Barquero S, Ruiz-León AM, Sierra-Pérez M, Estruch R, Casas R. Dietary Strategies for Metabolic Syndrome: A Comprehensive Review. Nutrients. 2020;12(10):2983. Published 2020 Sep 29. doi:10.3390/nu12102983
27. Amin AM. The metabolic signatures of cardiometabolic diseases: does the shared metabotype offer new therapeutic targets? Lifestyle Med. 2021;2(1):e25. doi:10.1002/lim2.25
28. Attaye I, van Oppenraaij S, Warmbrunn MV, Nieuwdorp M. The Role of the Intestinal Microbiotaon the Beneficial Effects of Ketogenic Diets. Nutrients. 2021;14(1):191. Published 2021 Dec 31. doi:10.3390/nu14010191
29. Merra G, Noce A, Marrone G, et al. Influence of Mediterranean Diet on Human Gut Microbiota. Nutrients. 2020;13(1):7. Published 2020 Dec 22. doi:10.3390/nu13010007
30. García-Curiel L, Pérez-Flores JG, González-Olivares LG, Guerrero-Solano JA, Contreras-López E, Pérez-Escalante E, Portillo-Torres LA, Sebastián-Nicolás JL. Probiotics and metabolic syndrome: a bibliometric analysis and overview of dietary interventions. Published 2024. doi:10.5772/intechopen.1004605
31. Mederle AL, Dima M, Stoicescu ER, Căpăstraru BF, Levai CM, Hațegan OA, Maghiari AL. Impact of gut microbiome interventions on glucose and lipid metabolism in metabolic diseases: a systematic review and meta-analysis. Life (Basel). 2024;14(11):1485. doi:10.3390/life14111485
32. Bubnov R. Towards individualized use of probiotics and prebiotics for metabolic syndrome and associated diseases treatment: does pathophysiology-based approach work and can anticipated evidence be completed? Preprints. Published 2018. doi:10.20944/preprints201809.0185.v1
33. Campos SB, Filho JGO, Salgaço MK, Jesus MHD, Egea MB. Effects of peanuts and pistachios on Intestinal Microbiotaand metabolic syndrome: a review. Foods. 2023;12(24):4440.

doi:10.3390/foods12244440

34. Lim WQ, Cheam JY, Law JWF, Letchumanan V, Lee LH, Tan LTH. Role of garlic in chronic diseases: focusing on Intestinal Microbiotamodulation. Prog Microbes Mol Biol. 2022;5(1). doi:10.36877/pmmb.a0000271

35. García-Curiel L, Pérez-Flores JG, González-Olivares LG, Guerrero-Solano JA, Contreras-López E, Pérez-Escalante E, Portillo-Torres LA, Sebastián-Nicolás JL. Probiotics and metabolic syndrome: a bibliometric analysis and overview of dietary interventions. Published 2024. doi:10.5772/intechopen.1004605. (Duplicate of Ref 30)

36. Feng X, Deng M, Zhang L, Pan Q. Impact of Intestinal Microbiotaand associated mechanisms on postprandial glucose levels in patients with diabetes. J Transl Int Med. 2023;11(4):363-371. Published 2023 Dec 20. doi:10.2478/jtim-2023-0116

37. Soemarie YB, Milanda T, Barliana MI. Fermented Foods as Probiotics: A Review. J Adv Pharm Technol Res. 2021;12(4):335-339. doi:10.4103/japtr.japtr_116_21

38. Pierre JF, Leone V, Martinez K. Journal of Nutritional Biochemistry special issue: nutritional modulation of the gut microbiome in gastrointestinal and metabolic disease. J Nutr Biochem. 2019;66:110-112. doi:10.1016/j.jnutbio.2019.01.008

39. Liu M, He C, Lv X, Zheng W, Yin J, Li Y, Ma J. Bile acid signaling mediates Intestinal Microbiotaregulation of host lipid metabolism. Front Microbiol. 2026;16:1696213. doi:10.3389/fmicb.2025.1696213

40. Papandreou C, Moré M, Bellamine A. Trimethylamine N-oxide in relation to cardiometabolic health—cause or effect? Nutrients. 2020;12(5):1330. doi:10.3390/nu12051330

41. Sahle Z, Engidaye G, Shenkute Gebreyes D, Adenew B, Abebe TA. Fecal microbiota transplantation and next-generation therapies: A review on targeting dysbiosis in metabolic disorders and beyond. SAGE Open Med. 2024;12:20503121241257486. Published 2024 May 31. doi:10.1177/20503121241257486

42. Paganelli FL, Luyer M, Hazelbag CM, et al. Roux-Y gastric bypass and sleeve gastrectomy directly change Intestinal Microbiotacomposition independent of surgery type. Sci Rep. 2019;9(1):10979. doi:10.1038/s41598-019-47332-z

43. Nogal B, Blumberg JB, Blander G, Jorge M. Gut microbiota-informed precision nutrition in the generally healthy individual: are we there yet? Curr Dev Nutr. 2021;5(9):nzab107. doi:10.1093/cdn/nzab107

44. Yu Y, Ding Y, Wang S, Jiang L. Intestinal Microbiotadysbiosis and its impact on type 2 diabetes: from pathogenesis to therapeutic strategies. Metabolites. 2025;15(6):397. doi:10.3390/metabo15060397

45. Pezzino S, Sofia M, Faletra G, Mazzone C, Litrico G, La Greca G, Latteri S. Gut-liver axis and non-alcoholic fatty liver disease: a vicious circle of dysfunctions orchestrated by the gut microbiome. Biology (Basel). 2022;11(11):1622. doi:10.3390/biology11111622

46. Nesci A, Carnuccio C, Ruggieri V, et al. GMand cardiovascular disease: evidence on the metabolic and inflammatory background of a complex relationship. Int J Mol Sci. 2023;24(10):9087. doi:10.3390/ijms24109087

47. Sun Y, Gao S, Ye C, Zhao W. GMdysbiosis in polycystic ovary syndrome: mechanisms of progression and clinical applications. Front Cell Infect Microbiol. 2023;13:1142041. doi:10.3389/fcimb.2023.1142041

48. Dedeepya SD, Goel V, Desai NN. Comment on "A Potential Ratio for Detecting Subclinical Atherosclerosis: Insight into Advanced NMR Lipid Profiles in Severe Obesity". J Cardiovasc Transl Res. 2026 Feb 17;19(1):22. doi: 10.1007/s12265-026-10747-x.