

Microbiome Modulation in Obesity: Role of Prebiotics and Probiotics in Hyperlipidemia Control

Nalongo Bina K.

Faculty of Medicine Kampala International University Uganda

ABSTRACT

Obesity is a major global health issue associated with metabolic disorders such as hyperlipidemia, which predisposes individuals to cardiovascular diseases. Emerging evidence highlights the critical role of the gut microbiome in modulating host metabolism, including lipid homeostasis, making it a potential target for therapeutic interventions. Prebiotics and probiotics, which can beneficially alter gut microbial composition and function, have gained considerable attention as non-pharmacological strategies to mitigate obesity-related hyperlipidemia. This review explores the mechanisms by which microbiome modulation through prebiotics and probiotics influences lipid metabolism and fat storage, focusing on their effects on dyslipidemia in obesity. It provides a detailed overview of the gut microbiota's role in lipid absorption, bile acid metabolism, and the regulation of lipoprotein profiles. Furthermore, the review assesses clinical evidence supporting the efficacy of prebiotics and probiotics in managing hyperlipidemia and obesity-related metabolic disorders. The therapeutic potential of these microbiome-targeted interventions is evaluated, alongside future directions for integrating microbiome modulation into obesity and hyperlipidemia treatment regimens.

Keywords: Obesity; Hyperlipidemia; Gut microbiome; Prebiotics; Probiotics

INTRODUCTION

Obesity and its related metabolic disorders, such as hyperlipidemia, are escalating public health concerns globally, contributing to a higher incidence of cardiovascular disease, type 2 diabetes, and non-alcoholic fatty liver disease [1–4]. The intricate relationship between obesity and lipid metabolism is significantly influenced by the gut microbiome, a complex community of microorganisms residing in the gastrointestinal tract [5–7]. The gut microbiota plays a pivotal role in various physiological processes, including energy homeostasis, lipid metabolism, and immune modulation, making it a crucial factor in the pathogenesis of obesity and hyperlipidemia [8]. The modulation of gut microbiota composition through diet, prebiotics, and probiotics has emerged as a promising strategy to counteract the adverse metabolic effects associated with obesity [9, 10]. Prebiotics, non-digestible food ingredients that selectively stimulate the growth and activity of beneficial gut bacteria, and probiotics, live microorganisms that confer health benefits, have been shown to influence lipid metabolism and improve lipid profiles in obese individuals [11, 12]. This review looks into the

role of prebiotics and probiotics in regulating hyperlipidemia, focusing on their effects on the gut microbiome and lipid metabolism.

Gut Microbiota and Lipid Metabolism in Obesity

The gut microbiota plays a fundamental role in regulating lipid metabolism by influencing dietary fat absorption, bile acid metabolism, and the synthesis of short-chain fatty acids (SCFAs), which impact lipogenesis and fat storage [7, 13]. Dysbiosis, an imbalance in gut microbial composition, is frequently observed in obese individuals and is associated with increased lipogenesis, reduced lipid oxidation, and the accumulation of lipids in adipose tissues [14, 15].

Mechanisms of Microbiota-Lipid Interaction

Bile Acid Metabolism: Gut bacteria are involved in the deconjugation and transformation of bile acids, which regulate lipid absorption and cholesterol homeostasis. Dysbiosis in obesity alters bile acid metabolism, leading to disrupted lipid profiles [16].

Short-Chain Fatty Acid Production: SCFAs such as acetate, propionate, and butyrate are

<https://www.inosr.net/inosr-experimental-sciences/> microbial metabolites that influence lipid metabolism by modulating energy expenditure, adipogenesis, and lipolysis[17, 18].

Lipoprotein Regulation: The gut microbiota impacts lipoprotein metabolism, including the synthesis and clearance of low-density lipoprotein (LDL) and high-density lipoprotein (HDL), contributing to hyperlipidemia in obese individuals[19].

Role of Prebiotics in Modulating Hyperlipidemia

Prebiotics, such as inulin, fructooligosaccharides (FOS), and galactooligosaccharides (GOS), have shown promising results in modulating the gut microbiome and improving lipid metabolism in obese individuals.[20, 21] Prebiotics promote the growth of beneficial bacterial species, such as *Bifidobacterium* and *Lactobacillus*, which are associated with improved lipid profiles.

Reduction in LDL Cholesterol: Prebiotic supplementation has been linked to reductions in LDL cholesterol levels, possibly through enhanced SCFA production and improved bile acid metabolism[22].

Improvement in HDL Levels: Certain prebiotics have been shown to increase HDL cholesterol levels, contributing to better cardiovascular outcomes in obese patients.

Anti-inflammatory Effects: By modulating the gut microbiome, prebiotics reduce systemic inflammation, which is often elevated in obesity and contributes to dyslipidemia [22].

Probiotics and Lipid Metabolism

Probiotics, particularly strains of *Lactobacillus* and *Bifidobacterium*, have been extensively studied for their lipid-lowering effects in both animal models and human clinical trials. Probiotic supplementation influences lipid metabolism through various mechanisms:

Cholesterol Assimilation: Some probiotic strains can directly assimilate cholesterol, reducing its absorption in the gut.

Modulation of Bile Acid Metabolism: Probiotics enhance the deconjugation of bile acids, which facilitates the excretion of cholesterol and improves lipid profiles.

The gut microbiome plays a critical role in the regulation of lipid metabolism and the development of obesity-related hyperlipidemia. Prebiotics and probiotics offer promising therapeutic approaches for modulating the gut microbiome and improving lipid profiles in obese individuals. While substantial evidence supports their potential benefits, further research is

Regulation of Lipid Transporters: Probiotics influence the expression of genes involved in lipid transport and metabolism, thereby improving lipoprotein profiles.

Clinical Evidence of Probiotics in Hyperlipidemia Control

Several clinical studies have demonstrated the efficacy of probiotic supplementation in reducing total cholesterol, LDL cholesterol, and triglyceride levels in obese individuals[23]. The administration of multi-strain probiotic formulations has shown greater lipid-lowering effects compared to single-strain supplements. Additionally, probiotics have been associated with reductions in visceral fat and improvements in markers of metabolic syndrome, further supporting their role in obesity management.

Synergistic Effects of Prebiotics and Probiotics (Synbiotics)

Combining prebiotics and probiotics, referred to as synbiotics, may offer enhanced benefits in modulating the gut microbiome and improving lipid metabolism[24]. Synbiotics provide a synergistic effect by promoting the survival and activity of probiotics in the gut, leading to greater improvements in lipid profiles and reductions in obesity-related inflammation.

Future Perspectives and Therapeutic Potential

The potential of prebiotics and probiotics to modulate the gut microbiome and control hyperlipidemia presents exciting opportunities for developing non-pharmacological treatments for obesity and related metabolic disorders. However, several challenges remain, including the need for personalized interventions based on individual microbiome compositions and the long-term effects of prebiotic and probiotic supplementation. Further research is needed to fully understand the mechanisms underlying microbiome-mediated lipid metabolism and to identify optimal strains and formulations for clinical use. Additionally, large-scale clinical trials are necessary to validate the efficacy of prebiotics, probiotics, and synbiotics in managing hyperlipidemia in diverse populations.

CONCLUSION

required to optimize these interventions for widespread clinical application. As our understanding of microbiome-host interactions deepens, the integration of microbiome modulation into obesity and hyperlipidemia management may become a cornerstone of future therapeutic strategies.

REFERENCES

1. Uti, D.E., Ibiyam, U.A., Omang, W.A., Udeozor, P.A., Umoru, G.U., Nwadam, S.K., Bawa, I., Alum, E.U., Mordi, J.C., Okoro, E.O., Obeten, U.N., Onwe, E.N., Zakari, S., Opotu, O.R., Aja, P.M.: Buchholzia coriacea Leaves Attenuated Dyslipidemia and Oxidative Stress in Hyperlipidemic Rats and Its Potential Targets in Silico. *Pharmaceutical Fronts.* 05, e141–e152 (2023). <https://doi.org/10.1055/s-0043-1772607>
2. Calcaterra, V., Verduci, E., Milanta, C., Agostinelli, M., Bona, F., Croce, S., Valsecchi, C., Avanzini, M.A., Zuccotti, G.: The Benefits of the Mediterranean Diet on Inflamm-Aging in Childhood Obesity. *Nutrients.* 16, 1286 (2024). <https://doi.org/10.3390/nu16091286>
3. Caslin, H.L., Bhanot, M., Bolus, W.R., Hasty, A.: Adipose tissue macrophages: unique polarization and bioenergetics in obesity. *Immunol Rev.* 295, 101–113 (2020). <https://doi.org/10.1111/imr.12853>
4. Uti, D.E., Atangwho, I.J., Eyong, E.U., Umoru, G.U., Egbung, G.E., Rotimi, S.O., Nna, V.U.: African Walnuts (*Tetracarpidium conophorum*) Modulate Hepatic Lipid Accumulation in Obesity via Reciprocal Actions on HMG-CoA Reductase and Paraoxonase. *Endocrine, Metabolic & Immune Disorders - Drug Targets (Formerly Current Drug Targets - Immune, Endocrine & Metabolic Disorders).* 20, 365–379 (2020). <https://doi.org/10.2174/1871530319666190724114729>
5. Yu, Y., Raka, F., Adeli, K.: The Role of the Gut Microbiota in Lipid and Lipoprotein Metabolism. *JCM.* 8, 2227 (2019). <https://doi.org/10.3390/jcm8122227>
6. Jian, Z., Zeng, L., Xu, T., Sun, S., Yan, S., Zhao, S., Su, Z., Ge, C., Zhang, Y., Jia, J., Dou, T.: The intestinal microbiome associated with lipid metabolism and obesity in humans and animals. *Journal of Applied Microbiology.* 133, 2915–2930 (2022). <https://doi.org/10.1111/jam.15740>
7. Schoeler, M., Caesar, R.: Dietary lipids, gut microbiota and lipid metabolism. *Rev Endocr Metab Disord.* 20, 461–472 (2019). <https://doi.org/10.1007/s11154-019-09512-0>
8. Tseng, C.-H., Wu, C.-Y.: The gut microbiome in obesity. *Journal of the Formosan Medical Association.* 118, S3–S9 (2019). <https://doi.org/10.1016/j.jfma.2018.07.009>
9. Sandra Tavares da Silva, C.A. dos S. y J.B., -: MICROBIOTA INTESTINAL; RELEVANCIA PARA LA OBESIDAD Y LA MODULACIÓN DE LOS. *NUTRICION HOSPITALARIA.* 1039–1048(2013). <https://doi.org/10.3305/nh.2013.28.4.6525>
10. Druart, C., Alligier, M., Salazar, N., Neyrinck, A.M., Delzenne, N.M.: Modulation of the Gut Microbiota by Nutrients with Prebiotic and Probiotic Properties. *Advances in Nutrition.* 5, 624S–633S(2014). <https://doi.org/10.3945/an.114.005835>
11. He, M., Shi, B.: Gut microbiota as a potential target of metabolic syndrome: the role of probiotics and prebiotics. *Cell & Bioscience.* 7,54(2017). <https://doi.org/10.1186/s13578-017-0183-1>
12. Cerdó, T., García-Santos, J., G. Bermúdez, M., Campoy, C.: The Role of Probiotics and Prebiotics in the Prevention and Treatment of Obesity. *Nutrients.* 11, 635 (2019). <https://doi.org/10.3390/nu11030635>
13. He, Y.-J., You, C.-G.: The Potential Role of Gut Microbiota in the Prevention and Treatment of Lipid Metabolism Disorders. *International Journal of Endocrinology.* 2020, 1–9 (2020). <https://doi.org/10.1155/2020/8601796>
14. Patra, D., Banerjee, D., Ramprasad, P., Roy, S., Pal, D., Dasgupta, S.: Recent insights of obesity-induced gut and adipose tissue dysbiosis in type 2 diabetes. *Front Mol Biosci.* 10, 1224982 (2023). <https://doi.org/10.3389/fmolb.2023.1224982>
15. Breton, J., Galmiche, M., Déchelotte, P.: Dysbiotic Gut Bacteria in Obesity: An Overview of the Metabolic Mechanisms and Therapeutic Perspectives of Next-Generation Probiotics. *Microorganisms.* 10, (2022). <https://doi.org/10.3390/microorganisms10020452>
16. Larabi, A.B., Masson, H.L.P., Bäumlér, A.J.: Bile acids as modulators of gut microbiota composition and function. *Gut Microbes.* 15, (2023). <https://doi.org/10.1080/19490976.2023.2172671>
17. May, K.S., den Hartigh, L.J.: Modulation of Adipocyte Metabolism by Microbial Short-

<https://www.inosr.net/inosr-experimental-sciences/>

- Chain Fatty Acids. *Nutrients*. 13, 3666 (2021).
<https://doi.org/10.3390/nu13103666>
18. Fusco, W., Lorenzo, M.B., Cintoni, M., Porcari, S., Rinninella, E., Kaitsas, F., Lener, E., Mele, M.C., Gasbarrini, A., Collado, M.C., Cammarota, G., Ianiro, G.: Short-Chain Fatty-Acid-Producing Bacteria: Key Components of the Human Gut Microbiota. *Nutrients*. 15, 2211 (2023).
<https://doi.org/10.3390/nu15092211>
19. Jia, X., Xu, W., Zhang, L., Li, X., Wang, R., Wu, S.: Impact of Gut Microbiota and Microbiota-Related Metabolites on Hyperlipidemia. *Front Cell Infect Microbiol*. 11, 634780 (2021).
<https://doi.org/10.3389/fcimb.2021.634780>
20. Yoo, S., Jung, S.-C., Kwak, K., Kim, J.-S.: The Role of Prebiotics in Modulating Gut Microbiota: Implications for Human Health. *Int J Mol Sci*. 25, 4834 (2024).
<https://doi.org/10.3390/ijms25094834>
21. Megur, A., Daliri, E.B.-M., Baltriukienė, D., Burokas, A.: Prebiotics as a Tool for the Prevention and Treatment of Obesity and Diabetes: Classification and Ability to Modulate the Gut Microbiota. *Int J Mol Sci*. 23, 6097 (2022).
<https://doi.org/10.3390/ijms23116097>
22. Song, X., Liu, Y., Zhang, X., Weng, P., Zhang, R., Wu, Z.: Role of intestinal probiotics in the modulation of lipid metabolism: implications for therapeutic treatments. *Food Science and Human Wellness*. 12, 1439–1449 (2023).
<https://doi.org/10.1016/j.fshw.2023.02.005>
23. Momin, E.S., Khan, A.A., Kashyap, T., Pervaiz, M.A., Akram, A., Mannan, V., Sanusi, M., Elshaikh, A.O.: The Effects of Probiotics on Cholesterol Levels in Patients With Metabolic Syndrome: A Systematic Review. *Cureus*. 15, e37567.
<https://doi.org/10.7759/cureus.37567>
24. Markowiak, P., Śliżewska, K.: Effects of Probiotics, Prebiotics, and Synbiotics on Human Health. *Nutrients*. 9, 1021 (2017).
<https://doi.org/10.3390/nu9091021>

Nalongo

CITE AS: Nalongo Bina K. (2024). Microbiome Modulation in Obesity: Role of Prebiotics and Probiotics in Hyperlipidemia Control. INOSR Experimental Sciences 13(3):20-23. <https://doi.org/10.59298/INOSRES/2024/1332023.000>