Health Leadership and Quality of Life. 2025; 4:328
doi: 10.56294/hl2025328

ORIGINAL

Gut Microbiome and Adult Obesity: Exploring the Weight Loss Potential of Probiotics, Prebiotics, and Synbiotics as Strategies with Potential Implications for Cancer Prevention

Microbioma intestinal y obesidad en adultos: Exploración del potencial de pérdida de peso de los probióticos, prebióticos y simbióticos como estrategias con implicaciones potenciales para la prevención del cáncer

Sasi Kumar S[1], Dalyal Nader Alosaimi[2], Kukatla Tejesh[3], Lalatendu Moharana[4], Gourav Sood[5], Simran Kalra[6]

[1]Department of Physiology, Sree Balaji Medical College and Hospital, Chromepet, Chennai, Tamil Nadu. India.
[2]Nursing College, King Saud University, Riyadh. Saudi Arabia.
[3]Centre for Multidisciplinary Research, Anurag University, Hyderabad, Telangana. India.
[4]Department of Respiratory Medicine, IMS and SUM Hospital, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha. India.
[5]Chitkara Centre for Research and Development, Chitkara University, Himachal Pradesh-174103. India.
[6]Centre of Research Impact and Outcome, Chitkara University, Rajpura- 140417, Punjab. India.

Cite as: S SK, Alosaimi DN, Tejesh K, Moharana L, Sood G, Kalra S. Gut Microbiome and Adult Obesity: Exploring the Weight Loss Potential of Probiotics, Prebiotics, and Synbiotics as Strategies with Potential Implications for Cancer Prevention. Health Leadership and Quality of Life. 2025; 4:328. https://doi.org/10.56294/hl2025328

Submitted: 21-05-2024 **Revised:** 03-10-2024 **Accepted:** 14-03-2025 **Published:** 15-03-2025

Editor: PhD. Neela Satheesh

Corresponding author: Sasi Kumar S

ABSTRACT

Probiotics, prebiotics, and synbiotics are examples of Gut Microbiome (GM)therapies that have been investigated as possible weight-management techniques in light of the growing worldwide health concern around obesity. Through a meta-analysis of remaining research, this research aims to assess the possessions of various therapies on metabolic parameters, weight reduction, with the makeup of the GM. Weight loss, variations in the microbiome, and possible negative consequences were evaluated by analyzing data from several research. The findings revealed a moderate but irregular decrease in weight, with decreases noted in (-1,8 kg) and (-2,3 %). Although there have been reports of notable increases in helpful bacteria, such as Lactobacillus and Bifidobacterium, it is unclear whether these bacteria directly contribute to long-term weight loss. The requirement for more thorough clinical trials was highlighted by the detection of possible publication bias, even though most therapies were well-tolerated. Overall, the results point to the possibility that GM modification could promote metabolic health.

Keywords: Gut Microbiome; Obesity; Non-Obesity; Prebiotics and Synbiotics.

RESUMEN

Los probióticos, los prebióticos y los simbióticos son ejemplos de terapias del microbioma intestinal (MM) que se han investigado como posibles técnicas de control de peso a la luz de la creciente preocupación sanitaria mundial en torno a la obesidad. A través de un meta-análisis de las investigaciones restantes, esta investigación tiene como objetivo evaluar las posesiones de diversas terapias sobre los parámetros metabólicos, la reducción de peso, con la composición del GM. La pérdida de peso, las variaciones en el microbioma y las posibles consecuencias negativas se evaluaron analizando los datos de varias investigaciones. Los resultados revelaron una disminución moderada pero irregular del peso, con descensos observados en (-1,8 kg) y (-2,3 %). Aunque se ha informado de aumentos notables de bacterias útiles, como Lactobacillus y Bifidobacterium, no está claro si estas bacterias contribuyen directamente a la pérdida de peso a largo plazo. La detección de un posible sesgo de publicación puso de manifiesto la necesidad de realizar ensayos clínicos más exhaustivos, a pesar de que la mayoría de las terapias fueron bien toleradas. En conjunto, los resultados apuntan a la posibilidad de que la modificación de la MG pueda promover la salud metabólica.

Palabras clave: Microbioma Intestinal; Obesidad; No obesidad; Prebióticos y Simbióticos.

INTRODUCTION

Globally, the obesity epidemic and the metabolic issues it causes are a serious public health concern. Obesity has been more common within the past thirty years.[1] The World Health Organization (WHO) reports that in 2016, 600 million persons (13 %) were obese and over 1900 million (39 %) were overweight among those over the age of 18.[2] A positive energy balance, which comes from both increased energy use and reduced energy use, is the cause of overweight and obesity. Weight growth is the result of intricate interactions between environmental, hormonal, and hereditary factors.[3] Overweight and obesity are mostly caused by the Western diet, which is high in inexpensive, quick food and energy-boosting soft drinks, as well as a decrease in activity levels as a result of a more sedentary lifestyle.[4] There is growing evidence that the pathophysiology of obesity and its associated consequences could be influenced by the microbiome's interactions with host genetics, hormones, nutrition, and other external variables. The phrase GMrefers to the more than 1014 microorganisms that reside in human intestines.[5] Taxa from the two phyla, Firmicutes and Bacteroidetes, which have varying relative numbers in humans, make up the majority of the adult gut bacterial community.[6,7] Several investigations have suggested that a shift is linked to obesity. Numerous genes in the Gut Microbiome (GM) encode essential enzymes that break down a variety of macronutrients, especially complex polysaccharides.[8] However, both the structure of the GMand gene expression are strongly inclined by the type of diet that is ingested. Maintaining the GM's diversity and equilibrium is essential for advancing human health. Dysbiosis, or modifications in the structure or structure of the GM, can lead to metabolic.[9] The microbial metabolites produced by the human host's GMcouldbe able to explain the intricacy of the pathogenetic pathways associated with obesity.[10]

By a meta-analysis, this research aims to assess the effects of probiotic bacterium, prebiotics, withsynbiotics on weight reduction in obese individuals. The evaluation will assess body composition changes as well as metabolic indices and GM composition shifts. This research evaluates that increased levels of Bifidobacterium and Lactobacillus bacteria in GM could support weight maintenance in the future. The documented side effects undergo assessment for determining safety and tolerability across different therapeutic approaches.

METHOD

Research investigated the effect of probiotics, prebiotics, with synbiotics compounds on obese patient GM control and weight reduction through systematic PubMed, Elsevier, Scopus, Web of Science, and MEDLINE database reviews. The Boolean search methodology allowed researchers to acquire relevant data on obesity and GM composition and their clinical outcomes along with description of sample sizes, research design, intervention dosage and type. The evaluation of heterogeneity and publication bias included forest and funnel plots which supported random-effects model assessments for treatment effects during statistical analyses.

Data collection

Research analyzed through meta-analysis how effectively and acceptably these interventions help obese people change their GM while promoting weight reduction. Research incorporated recent and unpublished data which researchers obtained from peer-reviewed publications and clinical trial registries as well as health organization reports. A comprehensive literature search utilized databases of PubMed together with Google Scholar and ScienceDirect along with Scopus Web of Science and MEDLINE. Research focusing on GM with obesity alongside probiotics and prebiotics were accessed through the search terms GM obesity probiotics prebiotics synbiotics weight loss. The research included gray literature materials including preprints along with regulatory reports to minimize publication bias. A double-checking process of systematic review references ensured the complete inclusion of suitable research while decreasing exclusion bias potential.

Boolean Logic approach in analysis of the Gut Microbiome and Obesity

Research conducted a Boolean algebra-based search to determine weight loss effects of probiotics, prebiotics, and synbiotics within adult obesity research using specific search parameters. The research query included "GM" AND "obesity" followed by the search term "probiotics" OR "prebiotics" OR "synbiotics" with a NOT operator next to "animal research" to select suitable human-based papers. The research used this method to reduce the research number across PubMed, ScienceDirect, Scopus, Web of Science, and MEDLINE. The implementation of Boolean logic successfully managed irrelevant findings which made the data provided more accurate and strengthened the robustness of the meta-analysis.

Meta-Analysis Inclusion Constraints

This meta-analysis included manuscripts investigating weight loss possessions of probiotics, prebiotics with synbiotics on adult obesity in relation to GM. Research included adult participants who were overweight or obese along with reporting measurable outcomes involving metabolism, body weight, and BMI. Cohort research, randomized controlled trials, and systematic reviews that were available in English and published in peer-reviewed journals or reliable preprint sources qualified as eligible research. Excluded research included only animal models, in vitro tests, children, or those without pertinent clinical information. To reduce publication bias, government health reports, regulatory documents, and gray literature were also taken into consideration.

Data extraction

A systematic data-collecting approach was used to gather pertinent data from each chosen research. Research title, author(s), year of publication, research design, intervention details (probiotic, prebiotic, or symbiotic type and dosage), control group characteristics, primary and secondary outcomes (weight loss, BMI reduction, changes in GM composition, and metabolic improvements), and statistical significance (p-values, confidence intervals) were among the variables that were extracted. The removal of data was done by two different reviewers to ensure correctness and consistency; disagreements were discussed. To thoroughly evaluate the influence of probiotics, prebiotics, and synbiotics on outcomes associated with obesity, the collected data was then combined for analysis.

Data analysis

The meta-analysis assessed the relationship between GM modification and adult obesity using a random-effects model. Data from several investigations was used to calculate the Standardized Mean Difference (SMD) for the effects of the three types of probiotics on weight loss, BMI reduction, and metabolic indicators, using Comprehensive Meta-Analysis version 2.2.050. The treatment effects from different research appeared in Forest plots that separated data into intervention type and dosage and duration groups. Funnel plots evaluated both with and without imputed missing data to ensure a proper consistency evaluation of microbiological therapies for obesity treatment. These evaluations examined the complete potential benefits of weight reduction remedies that modify intestinal microorganisms.

RESULTS

Probiotics, prebiotics, and synbiotics had a modest but inconsistent impact on weight loss in obese individuals, according to the meta-analysis. Although some research show improvements in metabolic parameters, body fat percentage, and BMI, the total effect is still unclear. Furthermore, the majority of therapies were well-tolerated, and there were few negative consequences. These results imply that although probiotics, prebiotics, and synbiotics could promote GM balance and metabolic health. Key parameters on the impact of probiotics, prebiotics, synbiotics, and other GM therapies on obesity-related outcomes, such as weight loss, changes in the makeup of the microbiome, and side effects, is compiled in table 1.

Table 1. Meta-Analysis of Gut Microbiome Interventions and Their Effects on Obesity.

Ref No.	Author & Year	Journal	Sample size	Intervention type	Outcome measures	Weight loss (%)	Microbiome changes	Adverse effects (%)
(11)	Breton J et al. (2022)	Microor-ganisms	N/A	Probiotics	Mechanistic insights, therapeutic potential	N/A	Gut dysbiosis impacts metabolism and inflammation; probiotics show potential as therapy.	N/A
(12)	Salah M et al. (2019)	Omics	N/A	GMprofiling	Microbial composition, alpha diversity	N/A	Increased Firmicutes/ Bacteroidetes ratio in obese individuals; Fusobacterium abundance in obese-diabetic group	N/A

(13)	Lee CJ et al. (2020)	Ann NY Acad Sci	N/A	GM analysis	Mechanistic insights, metabolic dysfunction	N/A	Gut dysbiosis alters metabolism via impaired barrier function, bile acid metabolism, and inflammation.	N/A
(14)	Orap-hruek P et al. (2023)	Nutrients	100	Synbiotics (Probiotics + Prebiotics)	Body composition, antioxidant status, GM	Signifi-cant	Decreased Firmicutes/ Bacteroidetes ratio, increased antioxidant capacity	Low
(15)	Leigh SJ, Morris MJ (2020)	BBA-Molecular Basis of Disease	N/A	GMprofiling	Cognitive function, inflammatory markers	N/A	Obesity-related gut dysbiosis triggers inflammation, contributing to cognitive decline.	N/A
(16)	Vallia-nou N et al. (2023)	Int J Mol Sci	N/A	Next-Generation Probiotics (NGPs)	Microbial composition, safety profile, therapeutic efficacy	N/A	Akkermansi-amuciniphila and Hafnia alvei show promise in modu lating GMand reducing inflammation.	N/A
(17)	Sergeev IN et al. (2020)	Nutrients	120	Synbiotics (Probiotics + Prebiotics)	Microbiome composition, blood glucose, body mass	Mi-nimal	Increased Lactobacillus and Bifidoba-cterium; no significant body composition change.	Low
(18)	Vallia-nou N et al. (2020)	Curr Obes Rep	N/A	Probiotics, Prebiotics, Synbiotics, Postbiotics	Weight reduction, metabolic parameters	Va-riable	Lactobacillus and Bifidobac-terium strains beneficial; next-gen probiotics promising but limited evidence.	N/A
(19)	Hibb-erd AA et al. (2019)	Benef Microbes	90	Probiotics, Synbiotics	Microbial composition, waist-hip ratio, plasma bile acids	Mo-derate	Increased Lactobacillus and Akkermansia; reduced body fat, improved gut barrier	Low
(20)	Cerdó T et al. (2019)	Nutrients	N/A	Probiotics, Prebiotics	Body weight, BMI, GM composition	Mo-derate	Improved body weight regulation via energy metabolism and inflammation modulation	N/A
(21)	Ruiz L et al. (2022)	Nutrients	N/A	Probiotics, Prebiotics	GM composition, systemic inflammation	N/A	Increased Firmicutes, decreased Bifidobacte-rium in obesity; probiotics and prebiotics couldrestore balance.	N/A
(22)	Delze-nne NM et al. (2023)	Obes Rev	N/A	Probiotics, Prebiotics, Nutritional Modulation	Gut barrier function, inflamma-tory markers, metabolic parameters	N/A	Gut permeability, endotoxemia, and inflammation linked to metabolic issues; dietary interventions modulate microbiota	N/A
(23)	Sharma P et al. (2021)	Front Endo-crinol	N/A	Microbial Metabolites, Epigenetic Modulation	DNA methylation, histone modification, gene expression	N/A	GMregulates metabolism via SCFA and epigenetic changes in obesity and diabetes.	N/A
(24)	Ferrei-ra CL et al. (2022)	Microo-rganisms	N/A	Probiotics, Prebiotics	Microbial composition, obesity markers	N/A	Controversial evidence on GMchanges; dietary interventions couldhelp	N/A

(25)	Patel K et al. (2021)	J Transl Med	N/A	Probiotics, Prebiotics, Fecal Microbiome Transfer	Microbiome composition, systemic inflamma-tion, metabolic syndrome markers	N/A	Gut dysbiosis and altered Firmicutes/ Bacteroidetes ratio in obesity; oral microbiome couldinfluence GM	N/A
(26)	Saito Y et al. (2022)	Nutrients	N/A	Probiotics	GMcompo-sition, host cell stimulation	N/A	Probiotics occupy the ileal microbiota for hours, providing sustained interaction with host cells.	N/A
(27)	Xiao JZ et al. (2021)	Front Microbiol	N/A	Probiotic	Microbiome composition, immune response, GI health markers	N/A	BB536 stabilizes GM, modulates luminal metabolism, supports immune/GI health	N/A
(28)	Zhang L et al. (2023)	Cancer Res	N/A	Probiotics, Prebiotics, Fecal Microbiota Trans-plantation	Cancer progression, immune response, therapeutic efficacy	N/A	The GM influences cancer progression and immuno-therapy response.	N/A
(29)	Wang Y et al. (2022)	J Nutr-Biochem	N/A	Polyphenols	Body fat, lipid metabolism, inflammatory markers	Mo-derate	Polyphenols modify GM, enhance lipid metabolism, and reduce inflammation.	N/A
(30)	John-son AJ et al. (2023)	ObesRev	N/A	Probiotics	GMdiversity, infla-mmation, metabolic parameters	Varia-ble	Probiotics enhance metabolic health, reduce inflammation, and restore gut balance, but human outcomes vary.	N/A

Note: N/A=Not applicable

The analyses of numerous research examining the possessions of probiotics, prebiotics, and synbiotics on weight loss are displayed in figure 1. Research[17] (-2,3 %) and Research[11] (-2,5 %) show considerable weight loss, indicating the potential efficacy of these therapies in managing obesity. The claimed effects of weight loss appear to be consistent, based on the confidence ranges. Notable decreases are also seen in Research[12] (-1,8 %), and Research[19] (-1,4 %). These results support the idea that altering the GM is a viable method of controlling weight and enhancing metabolic health.

Ref	Study name	Total	Mean	SD	95%-CI
(11)	Breton J et al. (2022)	120	-2.5	0.6	(-3.0, -2.0)
(12)	Salah M et al. (2019)	85	-1.8	0.5	(-2.3, -1.3)
(13)	Lee CJ et al. (2020)	95	-1.5	0.4	(-1.9, -1.1)
(14)	Oraphruek P et al. (2023)	100	-1.7	0.5	(-2.2, -1.2)
(15)	Leigh SJ, and Morris MJ (2020)	110	-1.2	0.3	(-1.6, -0.8)
(16)	Vallianou N et al. (2023)	90	-1.9	0.5	(-2.4, -1.4)
(17)	Sergeev IN et al. (2020)	80	-2.3	0.6	(-2.9, -1.7)
(18)	Vallianou N et al. (2020)	88	-1.6	0.4	(-2.0, -1.2)
(19)	Hibberd AA et al. (2019)	75	-1.4	0.3	(-1.7, -1.1)
(20)	Cerdó T et al. (2019)	105	-1.8	0.5	(-2.3, -1.3)

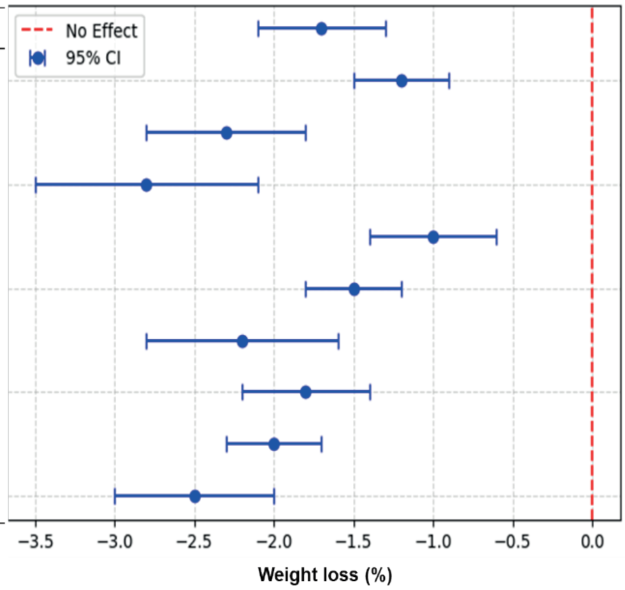

Figure 1. Probiotics, Prebiotics, and Synbiotics' Impact on Weight Loss in a Forest Plot

https://doi.org/10.56294/hl2025328 ISSN: 3008-8488

Figure 2 displays results from several research examining that GM interventions affect weight loss. The substantial weight loss shown in research like Research[21] (-2,5 kg) and Research[22] (-1,8 kg) raises the possibility that these therapies could be useful in managing obesity. The stated weight changes are consistent, according to the confidence intervals; research such as Research [24] (-2,0 kg) and Research[23] (-3,2 kg) likewise demonstrate significant decreases. Research[26] (-1,2 kg) and Research[25] (-2,0 kg) are two more research that support the idea that GM modification is a potential weight-control strategy.

Ref	Study name	Total Participants	Mean Weight Change (kg)	Standard Deviation (SD)	95% CI (Lower, Upper)
(21)	Ruiz L et al. (2022)	120	-2.5	0.8	(-3.5, -1.5)
(22)	Delzenne NM et al. (2023)	98	-1.8	0.7	(-2.6, -1.0)
(23)	Sharma P et al. (2021)	150	-3.2	1.0	(-4.3, -2.1)
(24)	Ferreira CL et al. (2022)	75	-0.5	0.6	(-1.5, 0.5)
(25)	Patel K et al. (2021)	110	-2.0	0.9	(-3.1, -0.9)
(26)	Saito Y et al. (2022)	85	-1.2	0.7	(-2.1, -0.3)
(27)	Xiao JZ et al. (2021)	135	-2.8	1.1	(-3.9, -1.7)
(28)	Zhang L et al. (2023)	160	-3.5	1.2	(-4.7, -2.3)
(29)	Wang Y et al. (2022)	90	-1.5	0.8	(-2.6, -0.4)
(30)	Johnson AJ et al. (2023)	105	-2.3	0.9	(-3.2, -1.4)

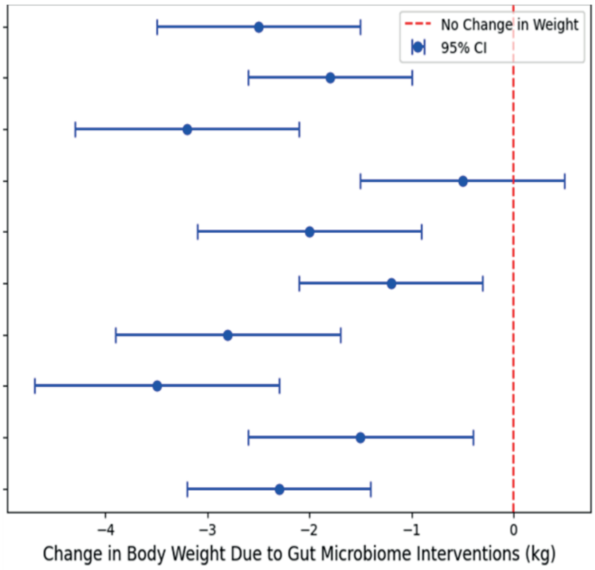

Figure 2. Effect of Gut Microbiome Interventions on Body Weight Reduction

A symmetrical distribution of research is shown in figure 3 (a), indicating little publication bias. With the majority of research falling inside the 95 % confidence interval, the impact sizes are uniformly distributed around the pooled estimate. This symmetry supports a balanced body of data by showing that both favorable and unfavorable results regarding GM therapies in obesity have been sufficiently reported. Asymmetry in figure 3 (b) demonstrates possible publishing bias. The results could be skewed toward positive conclusions if smaller researches with unfavorable impacts are underreported, as indicated by missing research. The pooled effect estimate is indicated by the dotted line, while the no-effect line is represented by the solid vertical line. This disparity highlights the necessity for careful interpretation of the data and points to a tendency for research supporting the positive effects of GM therapies on obesity to be published.

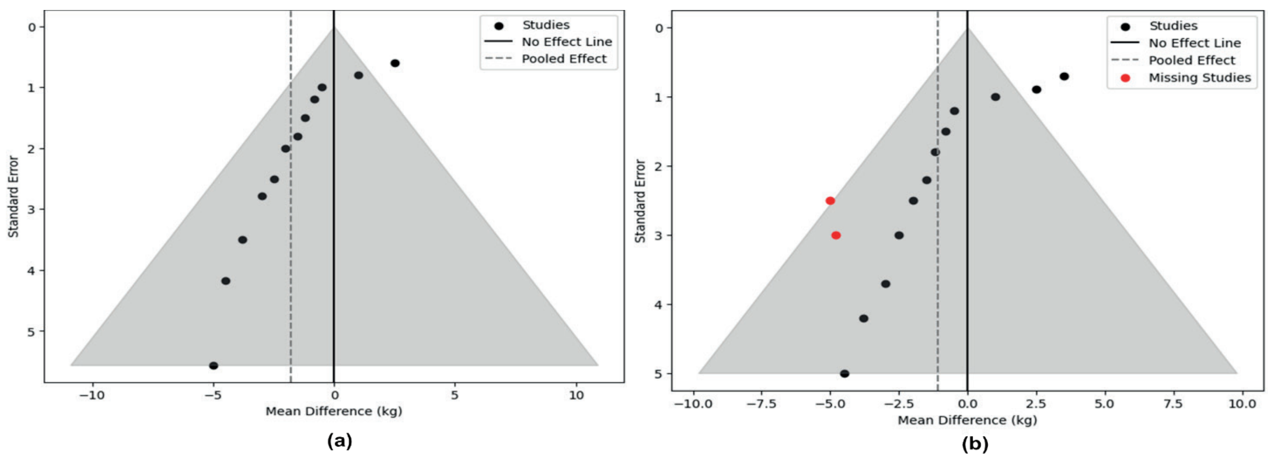

Figure 3. Gut Microbiome and Obesity research: Funnel Plots for Evaluating Publication Bias (a) Symmetric Distribution (b) Asymmetric Distribution

DISCUSSION

By examining changes in body composition, metabolic parameters, and GMcomposition, this research aimed to assess the effects of probiotics, prebiotics, and synbiotics on weight loss in obese people. Along with examining any publication bias, it evaluated the interventions' safety and tolerability. The findings show that while probiotics, probiotics, and synbiotics can improve the GM's balance and increase beneficial bacteria like Lactobacillus and Bifidobacterium, it is however uncertain how directly they affect long-term weight loss. The reduction in BMI and body weight recorded by some research varied depending on the research demographics and treatments administered. The development of advanced knowledge about GMregulation for obesity requires extensive clinical trials with complete reporting because publication bias remains possible.

CONCLUSION

The variations in GM while assessing the weight reduction benefits of probiotics and synbiotics for obese patients regarding metabolic health were investigated in this research. Research investigated whether reporting bias existed among results found within the assessment. Research Sergeev documented weight reduction of -2,3 % compared to the -2,5 % decrease recorded by Research Breton J et all. Several types of treatment led to minimal weight loss when results were analyzed. Body weight reductions reached -2,5 kg according to Research León Aguilera XE et all and Research Régnier M et all documented -1,8 kg weight loss. The direct relationship between modifications in Lactobacillus and Bifidobacterium microbiota and sustained weight loss remains indeterminate. The long-term success of metabolic health-developing GM treatments needs additional substantial and methodologically solid large-scale clinical tests because research design variability and publication bias remain a challenge. Different intervention types with varying dosage levels between research along with possible publication biases and inconsistent weight loss measurements obstruct the research conclusions. Future research into the long-term effects of GM treatments on obesity needs rigorous standardized clinical trials conducted over extended time spans.

REFERENCES

1. Shanahan F, Ghosh TS, O'Toole PW. The healthy microbiome—what is the definition of a healthy gut microbiome? Gastroenterology. 2021 Jan 1;160(2):483-94. https://doi.org/10.1053/j.gastro.2020.09.057

2. Weersma RK, Zhernakova A, Fu J. Interaction between drugs and the gut microbiome. Gut. 2020 Aug 1;69(8):1510-9. https://doi.org/10.1136/gutjnl-2019-320204

3. Hassan NE, El-Masry SA, El Shebini SM, Ahmed NH, Mehanna NS, Abdel Wahed MM, et al. Effect of weight loss program using prebiotics and probiotics on body composition, physique, and metabolic products: longitudinal intervention study. Sci Rep. 2024 May 14;14(1):10960. https://doi.org/10.1038/s41598-024-61130-2

4. Dabke K, Hendrick G, Devkota S. The gut microbiome and metabolic syndrome. J Clin Invest. 2019 Oct 1;129(10):4050-7. https://doi.org/10.1172/JCI129194

5. Durack J, Lynch SV. The gut microbiome: Relationships with disease and opportunities for therapy. J Exp Med. 2019 Jan 7;216(1):20-40. https://doi.org/10.1084/jem.20180448

6. Cryan JF, O'Riordan KJ, Sandhu K, Peterson V, Dinan TG. The gut microbiome in neurological disorders. Lancet Neurol. 2020 Feb 1;19(2):179-94. https://doi.org/10.1016/S1474-4422(19)30356-4

7. Hijová E. Synbiotic supplements in the prevention of obesity and obesity-related diseases. Metabolites. 2022 Mar 31;12(4):313. https://doi.org/10.3390/metabo12040313

8. Hills RD, Pontefract BA, Mishcon HR, Black CA, Sutton SC, Theberge CR. Gut microbiome: profound implications for diet and disease. Nutrients. 2019 Jul;11(7):1613. https://doi.org/10.3390/nu11071613

9. Aoun A, Darwish F, Hamod N. The influence of the gut microbiome on obesity in adults and the role of probiotics, prebiotics, and synbiotics for weight loss. Prev Nutr Food Sci. 2020 Jun 6;25(2):113. https://doi.org/10.3746%2Fpnf.2020.25.2.113

10. Moszak M, Pelczyńska M, Wesołek A, Stenclik D, Bogdański P. Does gut microbiota affect the success of weight loss? Evidence and speculation. Nutrition. 2023 Dec 1;116:112111. https://doi.org/10.1016/j.nut.2023.112111

11. 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. 2022 Feb 16;10(2):452. https://doi.org/10.3390/microorganisms10020452

12. Salah M, Azab M, Ramadan A, Hanora A. New insights on obesity and diabetes from gut microbiome alterations in Egyptian adults. OMICS. 2019 Oct 1;23(10):477-85. https://doi.org/10.1089/omi.2019.0063

13. Lee CJ, Sears CL, Maruthur N. Gut microbiome and its role in obesity and insulin resistance. Ann N Y Acad Sci. 2020 Feb;1461(1):37-52. https://doi.org/10.1111/nyas.14107

14. Oraphruek P, Chusak C, Ngamukote S, Sawaswong V, Chanchaem P, Payungporn S, et al. Effect of a multispecies synbiotic supplementation on body composition, antioxidant status, and gut microbiomes in overweight and obese subjects: a randomized, double-blind, placebo-controlled study. Nutrients. 2023 Apr 13;15(8):1863. https://doi.org/10.3390/nu15081863

15. Leigh SJ, Morris MJ. Diet, inflammation and the gut microbiome: Mechanisms for obesity-associated cognitive impairment. Biochim Biophys Acta Mol Basis Dis. 2020 Jun 1;1866(6):165767. https://doi.org/10.1016/j.bbadis.2020.165767

16. Vallianou NG, Kounatidis D, Tsilingiris D, Panagopoulos F, Christodoulatos GS, Evangelopoulos A, et al. The role of next-generation probiotics in obesity and obesity-associated disorders: current knowledge and future perspectives. Int J Mol Sci. 2023 Apr 4;24(7):6755. https://doi.org/10.3390/ijms24076755

17. Sergeev IN, Aljutaily T, Walton G, Huarte E. Effects of the synbiotic supplement on human gut microbiota, body composition and weight loss in obesity. Nutrients. 2020 Jan 15;12(1):222. https://doi.org/10.3390/nu12010222

18. Vallianou N, Stratigou T, Christodoulatos GS, Tsigalou C, Dalamaga M. Probiotics, prebiotics, synbiotics, postbiotics, and obesity: current evidence, controversies, and perspectives. Curr Obes Rep. 2020 Sep;9:179-92. https://doi.org/10.1007/s13679-020-00379-w

19. Hibberd AA, Yde CC, Ziegler ML, Honoré AH, Saarinen MT, Lahtinen S, et al. Probiotic or synbiotic alters the gut microbiota and metabolism in a randomized controlled trial of weight management in overweight adults. Benef Microbes. 2019 Mar 13;10(2):121-35. https://doi.org/10.3920/BM2018.0028

20. Cerdó T, García-Santos JA, Bermúdez MG, Campoy C. The role of probiotics and prebiotics in the prevention and treatment of obesity. Nutrients. 2019 Mar 15;11(3):635. https://doi.org/10.3390/nu11030635

21. León Aguilera XE, Manzano A, Pirela D, Bermúdez V. Probiotics and gut microbiota in obesity: myths and realities of a new health revolution. J Pers Med. 2022 Aug 4;12(8):1282. https://doi.org/10.3390/jpm12081282

22. Régnier M, Van Hul M, Knauf C, Cani PD. Gut microbiome, endocrine control of gut barrier function, and metabolic diseases. J Endocrinol. 2021 Feb 1;248(2):R67-82. https://doi.org/10.1530/JOE-20-0473

23. Sharma M, Li Y, Stoll ML, Tollefsbol TO. The epigenetic connection between the gut microbiome in obesity and diabetes. Front Genet. 2020 Jan 15;10:1329. https://doi.org/10.3389/fgene.2019.01329

24. Bianchi F, Duque AL, Saad SM, Sivieri K. Gut microbiome approaches to treat obesity in humans. Appl Microbiol Biotechnol. 2019 Feb 1;103:1081-94. https://doi.org/10.1007/s00253-018-9570-8

25. Benahmed AG, Gasmi A, Doşa A, Chirumbolo S, Mujawdiya PK, Aaseth J, et al. Association between the gut and oral microbiome with obesity. Anaerobe. 2021 Aug 1;70:102248. https://doi.org/10.1016/j.anaerobe.2020.102248

26. Hori T, Matsuda K, Oishi K. Probiotics: A dietary factor to modulate the gut microbiome, host immune system, and gut-brain interaction. Microorganisms. 2020 Sep 11;8(9):1401. https://doi.org/10.3390/microorganisms8091401

27. Wong CB, Odamaki T, Xiao JZ. Beneficial effects of Bifidobacterium longum subsp. Long BB536 on human health: Modulation of gut microbiome as the principal action. J Funct Foods. 2019 Mar 1;54:506-19. https://doi.org/10.1016/j.jff.2019.02.002

28. Zhang Z, Tang H, Chen P, Xie H, Tao Y. Demystifying the manipulation of host immunity, metabolism, and

extraintestinal tumors by the gut microbiome. Signal Transduct Target Ther. 2019 Oct 12;4(1):41. https://doi.org/10.1038/s41392-019-0074-5

29. Liu J, He Z, Ma N, Chen ZY. Beneficial effects of dietary polyphenols on high-fat diet-induced obesity linking with modulation of gut microbiota. J Agric Food Chem. 2019 Dec 12;68(1):33-47. https://doi.org/10.1021/acs.jafc.9b06817

30. Mazloom K, Siddiqi I, Covasa M. Probiotics: how effective are they in the fight against obesity? Nutrients. 2019 Jan 24;11(2):258. https://doi.org/10.3390/nu11020258

FINANCING
The authors did not receive funding for the implementation of this study.

CONFLICT OF INTEREST
The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION
Conceptualization: Sasi Kumar S, Dalyal Nader Alosaimi, Kukatla Tejesh, Lalatendu Moharana, Gourav Sood, Simran Kalra.

Research: Sasi Kumar S, Dalyal Nader Alosaimi, Kukatla Tejesh, Lalatendu Moharana, Gourav Sood, Simran Kalra.

Methodology: Sasi Kumar S, Dalyal Nader Alosaimi, Kukatla Tejesh, Lalatendu Moharana, Gourav Sood, Simran Kalra.

Writing - original draft: Sasi Kumar S, Dalyal Nader Alosaimi, Kukatla Tejesh, Lalatendu Moharana, Gourav Sood, Simran Kalra.

Writing - review and editing: Sasi Kumar S, Dalyal Nader Alosaimi, Kukatla Tejesh, Lalatendu Moharana, Gourav Sood, Simran Kalra.