Magna Scientia Advanced Research and Reviews
eISSN: 2582-9394
Cross Ref DOI: 10.30574/msarr
Journal homepage: https://magnascientiapub.com/journals/msarr/

(Review Article)

Role of *Lactobacillus plantarum* Strains in Gut Microbiota Interventions in Obese Patients: A Systematic Review and Meta-Analysis of Randomized Controlled Trials Studies

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Magna Scientia Advanced Research and Reviews, 2025, 15(02), 069-077

Publication history: Received 18 October 2025; revised on 25 November 2025; accepted on 27 November 2025

Article DOI: https://doi.org/10.30574/msarr.2025.15.2.0143

Abstract

Obesity is a multifactorial health condition arising from lifestyle imbalances and impaired metabolic regulation, often accompanied by gut microbial dysbiosis. Modulating the gut microbiota through probiotics has therefore gained attention as a therapeutic approach, with lactic acid bacteria such as *Lactobacillus plantarum* commonly used to help restore microbial balance. This study aimed to evaluate the effectiveness of *Lactobacillus plantarum* in improving body mass index (BMI) and lipid profiles in obese patients. A comprehensive literature search following PRISMA 2020 guidelines was conducted across PubMed, ScienceDirect, and Web of Science, and eligible studies were assessed using the Cochrane Risk of Bias 2.0 Tool. Data extraction captured key study characteristics, and a meta-analysis was performed using R Studio. The results demonstrated a significant reduction in BMI in the *Lactobacillus plantarum* group compared with controls (MD = −0.43; 95% CI: −0.65 to −0.21). Total cholesterol (MD = −6.76; 95% CI: −9.80 to −3.73) and LDL cholesterol (MD = −6.43; 95% CI: −8.88 to −3.98) also decreased significantly following the intervention. However, no meaningful improvements were observed for triglyceride or HDL cholesterol levels. In summary, *Lactobacillus plantarum* appears to be effective in reducing BMI, total cholesterol, and LDL cholesterol in obese individuals, although its influence on other lipid parameters remains limited. Therefore, selecting an appropriate probiotic strain should involve consideration of the desired metabolic outcomes, as well as formulation, dosage, and patient lifestyle.

Keywords: Obesity; Gut Microbiota; Probiotics; *Lactobacillus plantarum*

1. Introduction

Obesity is a multifactorial health problem characterized by a body mass index (BMI) of ≥25 kg/m^2 in the Asia-Pacific region or ≥30 kg/m^2 globally. Additional anthropometric indicators include waist circumference and waist-to-hip ratio, which correlate with obesity-related risks [1]. The prevalence of adult obesity in Indonesia reached 35% in 2018, forming a major public health challenge alongside undernutrition and micronutrient deficiencies [2,3].

The primary cause of obesity is an energy imbalance from sedentary lifestyles and excessive nutritious intake. Excess nutrients are stored in adipose tissue, a complex secretory organ involved in metabolism, inflammation, insulin sensitivity, bone metabolism, and hormonal regulation [4]. Obesity increases the risk of type 2 diabetes and

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cardiovascular complications such as atherosclerosis and hypertension [5]. Mortality related to obesity in Indonesia remained high, with 80.48 deaths per 100,000 population in 2019 [6].

Effective obesity management primarily involves sustainable lifestyle changes—healthy diet and increased physical activity—with pharmacotherapy recommended for BMI ≥27 and bariatric surgery for BMI ≥35[7]. Recent attention focuses on gut microbiota's role in obesity pathogenesis. Alterations in gut microbial composition contribute to disease progression, making microbiota modulation via probiotics—particularly *Lactobacillus plantarum*, a promising therapeutic strategy [8]. This bacterium is known for acid tolerance and metabolic benefits supporting cellular balance [9].

A systematic review and meta-analysis were performed to evaluate the efficacy of *Lactobacillus plantarum* probiotics in obesity management, addressing the scarcity of related research in Indonesia.

2. Materials and Methods

This study employed secondary data obtained through a Systematic Literature Review (SLR) and meta-analysis. Comprehensive searches were performed across electronic databases, including PubMed, Web of Science, and ScienceDirect, using keywords such as obesity, *Lactobacillus plantarum*, gut microbiota, therapy, along with their corresponding Medical Subject Headings (MeSH) terms. Quality assessment employed the Cochrane Risk of Bias tool for randomized trials (RoB 2), categorizing bias risk as low, high, or some concerns, which determined the overall bias level of each study.

2.1. Inclusion and Exclusion Criteria

This study includes randomized controlled trials published between 2019 and 2024 and ensures ethical approval compliance. Non-research sources such as book chapters, reports, conference proceedings, and review articles were excluded. Additionally, literature published in languages other than English and Indonesian, as well as studies with inaccessible full texts, were not considered.

2.2. Data Extraction and Management

Data extraction involved organizing key information into tables, including author, year, location, study design, population characteristics, sample size (total, experimental, control), participant age, *Lactobacillus plantarum* strain, intervention duration, and control type.

2.3. Statistical Analysis

All primary quantitative analyses were performed using R Studio. Effect sizes were measured by mean difference (MD) with 95% confidence intervals (CI). Results were considered statistically significant when the p-value was less than 0.05 ($p < 0.05$).

3. Results

The PRISMA 2020 guidelines were applied for this systematic review and meta-analysis. Initial searches using predefined keywords across PubMed, Science Direct, and Web of Science yielded 1,580 articles (1029, 334, and 217 respectively). After removing 208 duplicates, 1,372 articles underwent title and abstract screening, eliminating 1,362 as irrelevant. Full-text review of the remaining 10 articles led to exclusion of 4 studies due to population mismatch, intervention deviation, or inconsistent duration. Ultimately, 6 randomized controlled trials (RCTs) were included for further analysis. The flowchart reported in Figure 1 shows the entire study selection process. Risk of bias assessed by Cochrane RoB 2.0 indicated all six studies had low bias riss, as reported in Figure 2. All included studies have the same design—randomized controlled trials. Included studied shared a uniform intervention duration of 12 weeks, with dependent variables measured at baseline and post-intervention. Placebo served as the control variable across all selected studies. The characteristics of the included studies are summarized in Table 1.

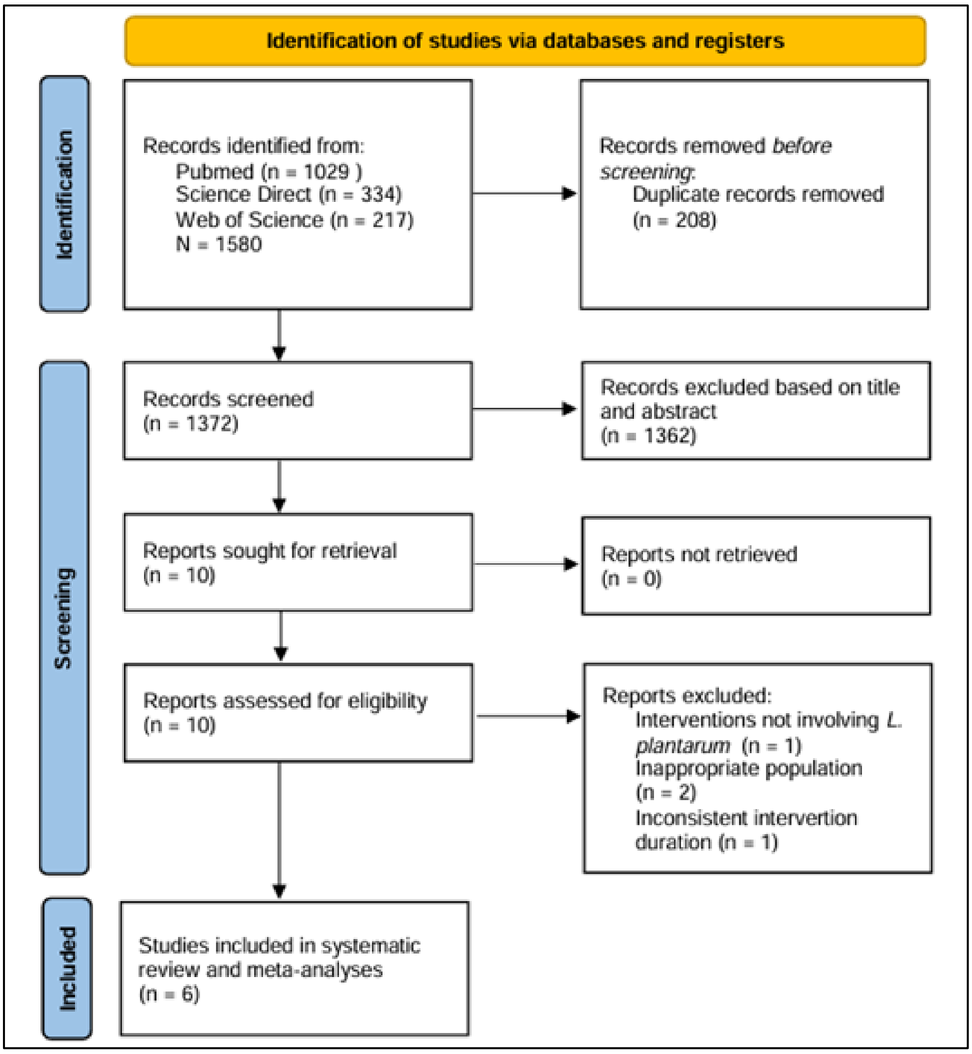

Figure 1 Flowchart of the literature selection process

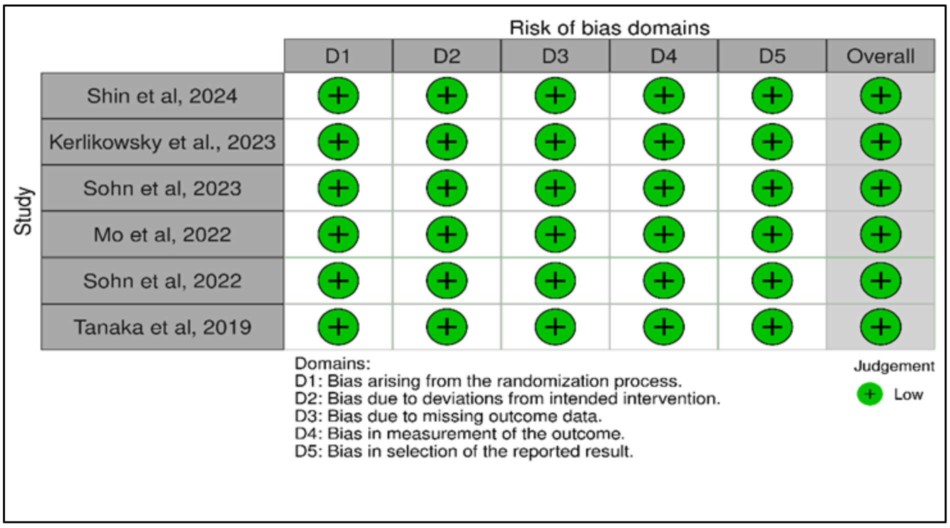

Figure 2 Visualization of ROB 2.0 quality analysis of the included studies

Table 1 Characteristics of included studies

Author, Year	Country	Population	Sample age		Sample size (experimental/control)	Intervention	Outcomes
			Experimental	Control			
Shin, 2024 [10]	Korea	BMI ≥ 25 kg/m^2 and < 30 kg/m	48.90 ± 10.60	47.14 ± 9.67	92 [45/47]	*L. plantarum* SKO-001	TC LDL-c HDL-c TGA
Kerlikowsky, 2023 [11]	Germany	BMI 18-35 kg/m^2	63.6 ± 7.0	63.3 ± 7.9	86 [43/43]	*L.plantarum* CECT7527, *L.plantarum* CECT7528, *L.plantarum* CECT7529	TC LDL-c HDL-c TGA
Sohn, 2023 [12]	Korea	BMI ≥ 25 kg/m^2 and < 30 kg/m^2	40.2 ± 11.2	40.1 ± 10.5	99 [50/49]	*L. plantarum* LMT1-48	BMI TC LDL-c HDL-c TGA
Mo, 2022 [13]	Korea	BMI 23.0 - 35.0 kg/m^2	35.7 ± 1.44	39.34 ± 1.61	72 [36/36]	*L. plantarum* KY-1032	BMI TC LDL-c HDL-c TGA
Sohn, 2022 [14]	Korea	BMI 25-30 kg/m^2	47.8 ± 11.7	45.5 ± 10.0	81 [41/40]	*L. plantarum* K50	BMI TC LDL-c HDL-c TGA
Tanaka, 2019 [15]	Japan	BMI > 23 kg/m^2 and < 30 kg/m^2	41.3 ± 10.2	42.1 ± 10.9	96 [49/47]	*L. plantarum* L-137	TC LDL-c HDL-c TGA
BMI, Body Mass Index; TC, Total Cholesterol; LDL-c, Low Density Lipoprotein-cholesterol; HDL-c, High Density Lipoprotein-cholesterol; TGA, Triglyceride							

Data analysis was conducted using R Studio, incorporating mean, standard deviation, and sample sizes for intervention and control groups. Heterogeneity was assessed for each parameter; a fixed-effect model was applied if $I^2 < 50\%$, otherwise a random-effect model was used.

This meta-analysis included three studies (Mo et al., 2022; Sohn et al., 2023; Sohn et al., 2022) reporting body mass index (BMI) outcomes (Figure 3). Statistical analysis revealed a significant BMI reduction of -0.43 (95% CI: -0.65 to -0.21) with no heterogeneity ($I^2 = 0\%$). This indicates a statistically significant decrease in BMI in the intervention group compared to controls [p = 0.0001].

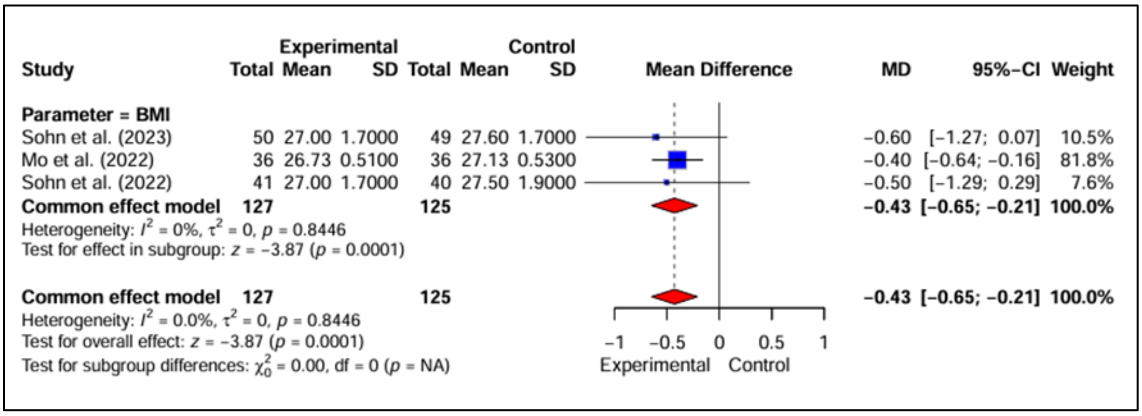

Figure 3 Meta-analysis of *Lactobacillus plantarum* effectiveness regarding BMI

Lipid profiles (HDL, LDL, total cholesterol, triglycerides) in obese patients were analyzed. Meta-analysis showed significant reductions in LDL, total cholesterol, and triglycerides ($p < 0.0001$) with high heterogeneity ($I^2 > 90\%$) (Figure 4). Subgroup LDL reduction was -6.43 (95% CI: -8.88 to -3.98), total cholesterol -6.76 (95% CI: -9.80 to -3.73), both significant. Triglycerides showed a non-significant change (-3.43; 95% CI: -15.57 to 8.70; p=0.5794). HDL analysis revealed no significant difference (0.77; 95% CI: -0.84 to 2.38; p=0.3468) with high heterogeneity ($I^2 = 99.8\%$) (Figure 5).

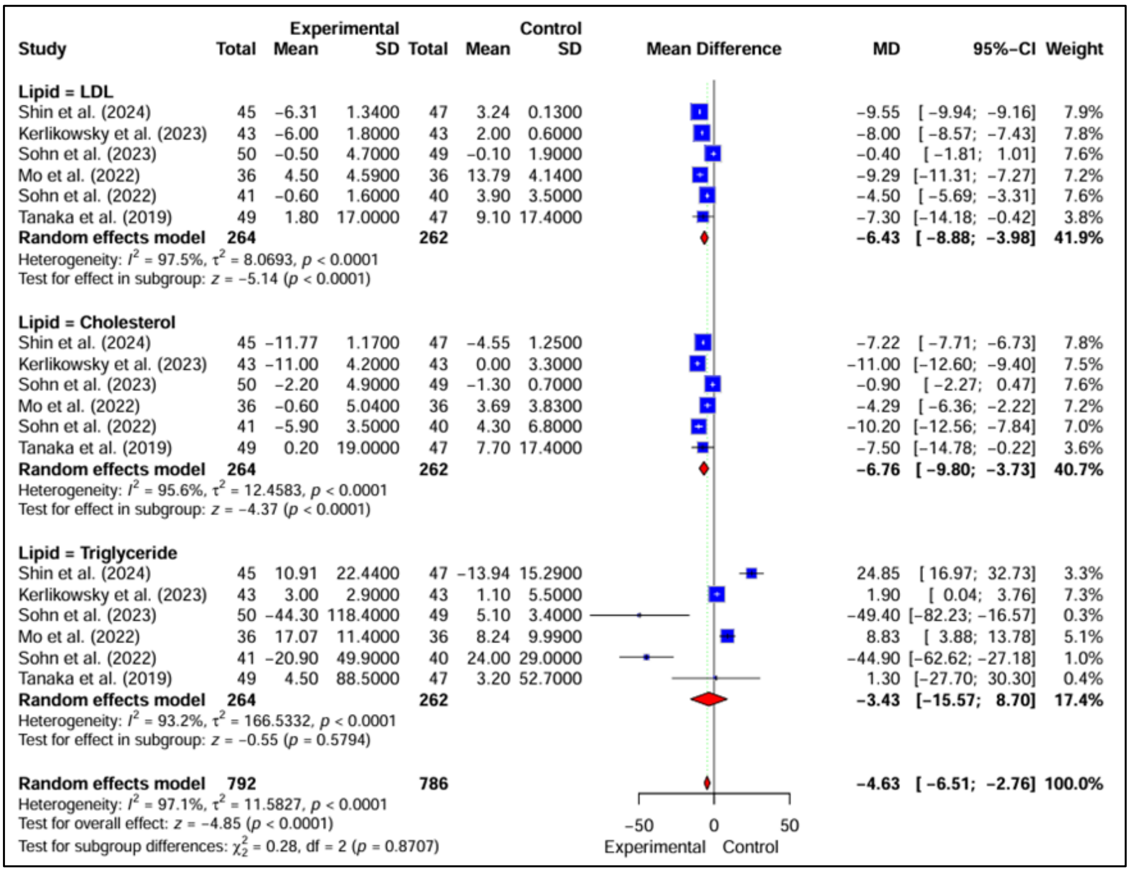

Figure 4 Meta-analysis of *Lactobacillus plantarum* effectiveness regarding lipid profile (total cholesterol, LDL cholesterol, and triglycerides)

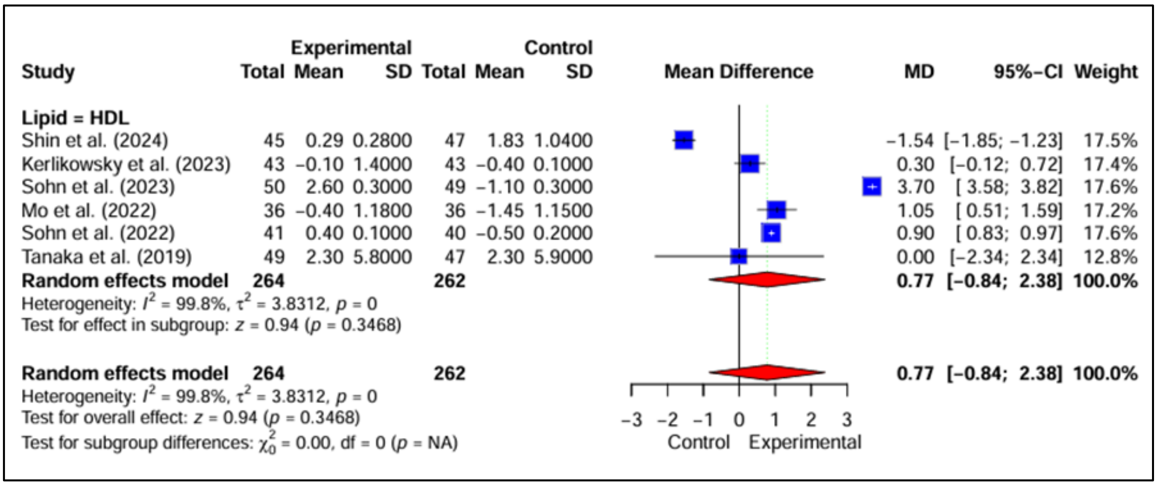

Figure 5 Meta-analysis of *Lactobacillus plantarum* effectiveness regarding lipid profile (HDL cholesterol)

4. Discussion

This systematic review and meta-analysis examined six randomized, double-blind controlled trials assessing the effects of *Lactobacillus plantarum* supplementation on obese patients across diverse populations from Korea, Germany, and Japan. Each study implemented a 12-week intervention involving a total of 527 participants, divided nearly equally between intervention (n=264) and control (n=263) groups. All participants met regional obesity criteria based on BMI, with most Asian studies adopting a BMI cutoff of 25 kg/m^2 and the German study using the international cutoff of 30 kg/m^2 [1]. Age ranged within adult populations, acknowledging increased obesity risks related to aging metabolic decline [16].

Individuals inherently regulate gut microbiota dynamics by releasing specific molecules such as microRNAs and nonspecific compounds including antimicrobial peptides, mucus, and immunoglobulin A, which collectively create a favorable environment for beneficial microbes while suppressing pathogenic bacteria to maintain intestinal homeostasis [17]. Gut microbiota composition is further influenced by factors such as age, mode of delivery, diet, and the intake of probiotics, prebiotics, and antibiotics. Disruption of this balance, termed dysbiosis, often results from unbalanced diet and lifestyle, characterized by a reduction in beneficial Bacteroidetes and an increase in Firmicutes, which is associated with altered metabolism, fat accumulation, and inflammation—key contributors to obesity [18,19]. Dysbiosis also impairs the production and function of short-chain fatty acids (SCFAs), metabolites integral to appetite regulation, insulin sensitivity, and anti-inflammatory responses, while compromising intestinal barrier integrity and increasing susceptibility to opportunistic pathogens [20–22]. *Lactobacillus plantarum*, a lactic acid bacterium, metabolizes carbohydrates producing lactic acid, ethanol/acetic acid, and carbon dioxide. Lactic acid acts as an antimicrobial metabolite. Additionally, *Lactobacillus plantarum* enhances mucin production and quality, and fortifies tight junctions between intestinal epithelial cells, thereby preserving gut barrier integrity. These mechanisms collectively restore optimal gut conditions conducive to the proliferation of beneficial microbiota, which are pivotal in maintaining host metabolic health [9,23,24].

Among the strains studied, LMT1-48 showed superior efficacy in decreasing BMI, as well as gradually reducing visceral and subcutaneous abdominal fat with effects becoming significant by the sixth week of administration [12]. This strain's anti-obesity effects are supported by animal studies showing downregulation of lipogenic genes and reduced fat accumulation [25]. In addition, *Lactobacillus plantarum* influences carbohydrate metabolism, which is closely linked to energy balance and obesity [26,27]. Given that carbohydrate intake correlates with body weight, *Lactobacillus plantarum*'s ability to regulate carbohydrate and lipid metabolism contributes to weight control and BMI reduction.

Dyslipidemia is a common complication of obesity, characterized by elevated triglycerides and LDL cholesterol, and decreased HDL cholesterol, increasing cardiovascular disease risk [28]. Meta-analysis of six randomized controlled trials reveals *Lactobacillus plantarum* supplementation significantly reduces total cholesterol and LDL levels compared to controls ($p < 0.0001$). Notably, a probiotic capsule combining strains CECT7527, CECT7528, and CECT7529 showed the most pronounced effect. The strain SKO-001 demonstrated optimal LDL reduction, aligning with evidence that *Lactobacillus plantarum* inhibits cholesterol synthesis enzymes (HMG-CoA reductase) and decreases cholesterol absorption by breaking down bile salts, facilitating cholesterol excretion via feces [29]. Moreover, modulation of gut microbiota and increased production SCFAs by lactic acid bacteria contribute to its cholesterol lowering ability [14]. Another mechanism involves improving intestinal barrier integrity, preventing endotoxin translocation; this is crucial since obesity-associated microbiota imbalance elevates pro-inflammatory lipopolysaccharide (LPS) levels, which stimulate hepatic cholesterol production [15,30]. Triglycerides, associated with leptin resistance and cognitive function, showed no significant difference between intervention and control groups (p=0.5794), although strains K50 and LMT1-48 reduced levels significantly in some studies [12,14]. The nonsignificant difference in triglyceride levels between the intervention and control groups reported by Shin et al. (2024) was due to an increase in triglycerides in the intervention group and a decrease in the control group. This result contrasts with an experimental study using the same strain on high-fat-diet-induced obese mice which showed different outcomes [25]. This discrepancy may stem from individual variations in response to the intervention applied by Shin et al. [2024], highlighting how personal biological differences can influence study results despite similar experimental conditions [10]. HDL cholesterol levels were unchanged overall (p=0.3468), although strain LMT1-48 optimally increased HDL, possibly through shifts in gut genera like *Oscillate* [14]. Detection of HDL changes may be enhanced when probiotic use is combined with physical activity [10]. Further research may need to clarify effects on triglycerides and HDL cholesterol and optimize strain selection.

5. Conclusion

Lactobacillus plantarum significantly reduces body mass index (BMI) in obese patients and exhibits a significant positive effect on lipid metabolism, particularly in lowering total cholesterol and LDL cholesterol levels. The choice of *Lactobacillus plantarum* strain should be individualized, taking into account the desired therapeutic effects, formulation type, dosage, and the patient's lifestyle.

Compliance with ethical standards

Acknowledgments

I sincerely thank my supervisor for their invaluable guidance and support throughout this research. I gratefully acknowledge Airlangga University for providing essential resources and facilities. I also appreciate my colleagues and friends for their insightful discussions and consistent encouragement. Their combined contributions have been fundamental to this study.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Obesity and overweight [Internet]. [cited 2025 Nov 21]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

[2] Badan Penelitian dan Pengembangan Kesehatan. Laporan Nasional Riskesdas 2018. Riset Kesehatan Dasar. Lembaga Penerbit Badan Penelitian dan Pengembangan Kesehatan; 2019. 674 p.

[3] UNICEF. Analisis Lanskap Kelebihan Berat Badan dan Obesitas di Indonesia. Ringkasan Temuan Kunci [Internet]. Jakarta; 2024 [cited 2025 Nov 21]. Available from: https://www.unicef.org/indonesia/media/22496/file/Analisis%20Lanskap%20Kelebihan%20Berat%20Badan%20dan%20Obesitas%20di%20Indonesia:%20Ringkasan%20Temuan%20Kunci.pdf

[4] Khanna D, Welch BS, Rehman A. Pathophysiology of Obesity. Diabetologie [Internet]. 2022 Oct 20 [cited 2025 Nov 21];20[3]:312–9. Available from: https://www.ncbi.nlm.nih.gov/books/NBK572076/

[5] Jia W, Liu F. Obesity: causes, consequences, treatments, and challenges. J Mol Cell Biol [Internet]. 2021 Jul 1 [cited 2025 Nov 21];13[7]:463–5. Available from: https://pubmed.ncbi.nlm.nih.gov/34673982/

[6] Ritchie H, Roser M. Vol. 126, Our World in Data. 2017 [cited 2025 Nov 21]. p. 126–32 Obesity. Available from: https://ourworldindata.org/obesity

[7] Garvey WT, Mechanick JI, Brett EM, Garber AJ, Hurley DL, Jastreboff AM, et al. American association of clinical endocrinologists and American college of endocrinology comprehensive clinical practice guidelines for medical care of patients with obesity: Executive summary. Endocrine Practice [Internet]. 2016 Jul 1 [cited 2025 Nov

21];22[7]:842–84. Available from: https://www.endocrinepractice.org/action/showFullText?pii=S1530891X20392144

[8] Geng J, Ni Q, Sun W, Li L, Feng X. The links between gut microbiota and obesity and obesity related diseases. Biomedicine and Pharmacotherapy [Internet]. 2022 Mar 1 [cited 2025 Nov 21];147. Available from: https://pubmed.ncbi.nlm.nih.gov/35134709/

[9] Fidanza M, Panigrahi P, Kollmann TR. Lactiplantibacillus plantarum-Nomad and Ideal Probiotic. Front Microbiol [Internet]. 2021 Oct 6 [cited 2025 Nov 21];12. Available from: https://pubmed.ncbi.nlm.nih.gov/34690957/

[10] Shin SM, Park JS, Kim SB, Cho YH, Seo H, Lee HS. A 12-Week, Single-Centre, Randomised, Double-Blind, Placebo-Controlled, Parallel-Design Clinical Trial for the Evaluation of the Efficacy and Safety of Lactiplantibacillus plantarum SKO-001 in Reducing Body Fat. Nutrients [Internet]. 2024 Apr 11 [cited 2025 Nov 21];16[8]. Available from: https://pubmed.ncbi.nlm.nih.gov/38674828/

[11] Kerlikowsky F, Müller M, Greupner T, Amend L, Strowig T, Hahn A. Distinct Microbial Taxa Are Associated with LDL-Cholesterol Reduction after 12 Weeks of Lactobacillus plantarum Intake in Mild Hypercholesterolemia: Results of a Randomized Controlled Study. Probiotics and Antimicrobial Proteins 2023 17:3 [Internet]. 2023 Nov 28 [cited 2025 Nov 21];17[3]:1086–95. Available from: https://link.springer.com/article/10.1007/s12602-023-10191-2

[12] Sohn M, Jung H, Lee WS, Kim TH, Lim S. Effect of Lactobacillus plantarum LMT1-48 on Body Fat in Overweight Subjects: A Randomized, Double-Blind, Placebo-Controlled Trial. Diabetes Metab J [Internet]. 2023 Jan 1 [cited 2025 Nov 21];47[1]:92–103. Available from: https://pubmed.ncbi.nlm.nih.gov/35487505/

[13] Mo SJ, Lee K, Hong HJ, Hong DK, Jung SH, Park SD, et al. Effects of Lactobacillus curvatus HY7601 and Lactobacillus plantarum KY1032 on Overweight and the Gut Microbiota in Humans: Randomized, Double-Blinded, Placebo-Controlled Clinical Trial. Nutrients [Internet]. 2022 Jun 1 [cited 2025 Nov 21];14[12]. Available from: https://pubmed.ncbi.nlm.nih.gov/35745214/

[14] Sohn M, Na GY, Chu J, Joung H, Kim BK, Lim S. Efficacy and Safety of Lactobacillus plantarum K50 on Lipids in Koreans With Obesity: A Randomized, Double-Blind Controlled Clinical Trial. Front Endocrinol [Lausanne] [Internet]. 2022 Jan 19 [cited 2025 Nov 21];12. Available from: https://pubmed.ncbi.nlm.nih.gov/35126309/

[15] Tanaka Y, Hirose Y, Yamamoto Y, Yoshikai Y, Murosaki S. Daily intake of heat-killed Lactobacillus plantarum L-137 improves inflammation and lipid metabolism in overweight healthy adults: a randomized-controlled trial. Eur J Nutr [Internet]. 2020 Sep 1 [cited 2025 Nov 21];59[6]:2641–9. Available from: https://pubmed.ncbi.nlm.nih.gov/31620886/

[16] Saraswati SK, Dhista Rahmaningrum F, Naufal Zidane Pahsya M, Paramitha N, Wulansari A, Rossa Ristantya A, et al. Literature Review : Faktor Risiko Penyebab Obesitas. MEDIA KESEHATAN MASYARAKAT INDONESIA [Internet]. 2021 Feb 1 [cited 2025 Nov 21];20[1]:70–4. Available from: https://ejournal.undip.ac.id/index.php/mkmi/article/view/34930

[17] Hasan N, Yang H. Factors affecting the composition of the gut microbiota, and its modulation. PeerJ [Internet]. 2019 [cited 2025 Nov 21];7[8]. Available from: https://pubmed.ncbi.nlm.nih.gov/31440436/

[18] 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 [Internet]. 2022 Feb 1 [cited 2025 Nov 21];10[2]. Available from: https://pubmed.ncbi.nlm.nih.gov/35208906/

[19] Noor J, Chaudhry A, Batool S, Noor R, Fatima G. Exploring the Impact of the Gut Microbiome on Obesity and Weight Loss: A Review Article. Cureus [Internet]. 2023 Jun 26 [cited 2025 Nov 21];15[6]. Available from: https://pubmed.ncbi.nlm.nih.gov/37503494/

[20] Anachad O, Taouil A, Taha W, Bennis F, Chegdani F. The Implication of Short-Chain Fatty Acids in Obesity and Diabetes. Microbiol Insights [Internet]. 2023 Jan [cited 2025 Nov 21];16. Available from: https://pubmed.ncbi.nlm.nih.gov/36994236/

[21] Faradilah A, Bukhari A, Aminuddin A, Syauki AY. The role of obesity in altering the effects of short chain fatty acids [SCFA] on metabolic hormone regulation: A systematic review and meta-analysis. Clinical Nutrition Open Science [Internet]. 2025 [cited 2025 Nov 21];60:181–99. Available from: http://creativecommons.org/licenses/by/4.0/

[22] Pérez-Reytor D, Puebla C, Karahanian E, García K. Use of Short-Chain Fatty Acids for the Recovery of the Intestinal Epithelial Barrier Affected by Bacterial Toxins. Front Physiol. 2021 May 24;12.

[23] Dempsey E, Corr SC. Lactobacillus spp. for Gastrointestinal Health: Current and Future Perspectives. Front Immunol [Internet]. 2022 Apr 6 [cited 2025 Nov 21];13:840245. Available from: www.frontiersin.org

[24] Zeng Z, Huang Z, Yue W, Nawaz S, Chen X, Liu J. Lactobacillus plantarum modulate gut microbiota and intestinal immunity in cyclophosphamide-treated mice model. Biomedicine and Pharmacotherapy [Internet]. 2023 Dec 31 [cited 2025 Nov 21];169. Available from: https://pubmed.ncbi.nlm.nih.gov/37979376/

[25] Choi WJ, Dong HJ, Jeong HU, Ryu DW, Song SM, Kim YR, et al. Lactobacillus plantarum LMT1-48 exerts anti-obesity effect in high-fat diet-induced obese mice by regulating expression of lipogenic genes. Sci Rep [Internet]. 2020 Dec 1 [cited 2025 Nov 21];10[1]:869. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6972779/

[26] Cui Y, Wang M, Zheng Y, Miao K, Qu X. The Carbohydrate Metabolism of Lactiplantibacillus plantarum. Int J Mol Sci [Internet]. 2021 Dec 1 [cited 2025 Nov 21];22[24]. Available from: https://pubmed.ncbi.nlm.nih.gov/34948249/

[27] Bayer S, Holzapfel C. Carbohydrate intake - current knowledge on weight management. Curr Opin Clin Nutr Metab Care [Internet]. 2022 Jul 1 [cited 2025 Nov 21];25[4]:265–70. Available from: https://pubmed.ncbi.nlm.nih.gov/35762163/

[28] Feingold KR. Obesity and Dyslipidemia. Endotext [Internet]. 2023 Jun 19 [cited 2025 Nov 21]; Available from: https://www.ncbi.nlm.nih.gov/books/NBK305895/

[29] Hao Y, Li J, Wang J, Chen Y. Mechanisms of Health Improvement by Lactiplantibacillus plantarum Based on Animal and Human Trials: A Review. Fermentation 2024, Vol 10, Page 73 [Internet]. 2024 Jan 23 [cited 2025 Nov 21];10[2]:73. Available from: https://www.mdpi.com/2311-5637/10/2/73/htm

[30] Wang K, Lai W, Min T, Wei J, Bai Y, Cao H, et al. The Effect of Enteric-Derived Lipopolysaccharides on Obesity. International Journal of Molecular Sciences 2024, Vol 25, Page 4305 [Internet]. 2024 Apr 13 [cited 2025 Nov 21];25[8]:4305. Available from: https://www.mdpi.com/1422-0067/25/8/4305/htm