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ASSESSING PROBIOTIC YOGURT SUPPLEMENTATION ON METABOLIC INFLAMMATION IN SEDENTARY ADULTS

Original Article

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Abstract

Background: Sedentary lifestyles are increasingly recognized as contributors to low-grade systemic inflammation and dysregulated lipid metabolism, predisposing individuals to metabolic disorders. Probiotics, particularly when administered through fermented foods such as yogurt, have demonstrated potential in modulating inflammatory processes and lipid profiles by improving gut microbiota composition and immune regulation.

Objective: To examine whether daily supplementation with probiotic-enriched yogurt reduces inflammatory markers and improves lipid profiles compared to plain yogurt among sedentary adults.

Methods: This randomized controlled trial enrolled 120 sedentary adults from South Punjab, who were equally allocated to either a probiotic yogurt group or a plain yogurt group. Over a twelve-week period, each participant consumed 200 grams of their assigned yogurt daily. Baseline and post-intervention blood samples were analyzed to determine serum concentrations of high-sensitivity C-reactive protein (hs-CRP), interleukin-6 (IL-6), total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides. Changes within and between the groups were evaluated using paired and independent t-tests, with statistical significance defined as $p < 0.05$.

Results: Compared to the control group, the probiotic yogurt group showed statistically significant reductions in hs-CRP (-1.9 ± 0.7 mg/L) and IL-6 (-0.8 ± 0.3 pg/mL), as well as notable favorable changes in LDL (-12.4 ± 4.6 mg/dL) and HDL ($+4.5 \pm 1.8$ mg/dL) levels ($p < 0.05$). No adverse effects were observed, and participant compliance was greater than 90%.

Conclusion: Probiotic-enriched yogurt effectively attenuated metabolic inflammation and improved lipid regulation among sedentary adults. Regular consumption may serve as a practical dietary strategy to mitigate early metabolic risks associated with physical inactivity.

Keywords: Adult; Dietary Supplements; Inflammation; Lipid Metabolism; Probiotics; Randomized Controlled Trial; Sedentary Lifestyle; Yogurt

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Introduction

Metabolic inflammation, a low-grade systemic inflammatory state, has emerged as a key contributor to the global epidemic of non-communicable diseases, including obesity, type 2 diabetes, and cardiovascular disorders(1). Characterized by elevated circulating cytokines and impaired immune regulation, metabolic inflammation develops silently in individuals with sedentary lifestyles and unbalanced diets(2). The modern era of physical inactivity, coupled with excessive caloric intake, promotes visceral adiposity and dysregulated lipid metabolism, both of which play a pivotal role in sustaining chronic inflammation(3). This subtle yet persistent inflammatory milieu underlies insulin resistance, endothelial dysfunction, and lipid abnormalities that collectively accelerate cardiometabolic risk. Within this context, identifying non-pharmacological strategies to modulate inflammation and improve metabolic health has become a pressing clinical and public health priority(4).

Contemporary research has increasingly identified the gut microbiome as a pivotal modulator of both metabolism and immune function (5). The gut microbiota serves as a crucial link connecting dietary intake with overall systemic well-being, exerting influence over inflammatory processes, lipid handling, and insulin responsiveness. Dysbiosis—a disruption in the normal microbial balance—is correlated with increased gut barrier dysfunction, allowing bacterial endotoxins like lipopolysaccharides to enter the bloodstream. This triggers innate immune mechanisms, resulting in a state of persistent, low-level systemic inflammation (6). Consequently, strategies aimed at re-establishing a balanced microbiota through diet, with probiotics being a prime example, are being explored as a viable method to mitigate the metabolic issues linked to physical inactivity (7).

Probiotics, which are live microbial agents that promote health when consumed in sufficient quantities, have been studied for their capacity to regulate inflammation and lipid metabolism (8). Specific strains belonging to the *Lactobacillus* and *Bifidobacterium* genera have exhibited properties that can modulate the immune system, such as downregulating pro-inflammatory cytokines and strengthening the integrity of the intestinal lining (9). Evidence from human trials and experimental models indicates that probiotic intake may lower circulating concentrations of inflammatory biomarkers, including C-reactive protein, tumor necrosis factor-alpha, and interleukin-6. Additionally, probiotic use has been associated with favorable alterations in lipid parameters, such as decreased total cholesterol and low-density lipoprotein (LDL) and elevated high-density lipoprotein (HDL) levels. Despite these observations, the reliability and extent of these benefits are still unclear, primarily because of inconsistencies in the types of probiotic strains used, their preparations, administered doses, and characteristics of the study cohorts (10).

Yogurt, a widely consumed fermented dairy product, serves as a convenient and acceptable vehicle for probiotic delivery. Beyond its nutritional value, yogurt enriched with live bacterial cultures may provide synergistic benefits by combining the bioactive properties of fermentation products with probiotic functionality(5). Regular consumption of yogurt has been associated with improved gut health, enhanced immune regulation, and favorable metabolic outcomes(6). Yet, despite its popularity, evidence comparing the metabolic effects of probiotic-enriched yogurt versus plain yogurt in sedentary adults remains limited(6). This population, often characterized by minimal physical activity and suboptimal metabolic health, represents a critical target group for preventive nutritional interventions.

The sedentary lifestyle, prevalent in both developed and developing regions, profoundly impacts metabolic equilibrium. Inactivity disrupts glucose and lipid metabolism, fosters adipose tissue inflammation, and contributes to the early development of insulin resistance even among individuals without obesity(7). The interplay between physical inactivity, gut dysbiosis, and systemic inflammation forms a self-perpetuating cycle that accelerates metabolic decline. Nutritional strategies capable of modifying gut microbiota composition, thereby attenuating inflammation, could offer a simple yet effective approach to improving metabolic resilience in sedentary individuals. Probiotic yogurt supplementation stands out as a practical intervention, easily incorporated into daily routines without requiring drastic lifestyle modifications(8).

Despite mounting evidence of the anti-inflammatory potential of probiotics, existing studies often involve heterogeneous populations or focus on individuals with overt metabolic disease. Limited research has examined healthy but sedentary adults—a group at risk yet amenable to preventive measures. Moreover, the comparative effectiveness of probiotic-enriched yogurt versus conventional yogurt has not been systematically evaluated in this demographic. Understanding whether the addition of probiotic strains to an everyday dietary item like yogurt can yield measurable improvements in inflammatory and lipid markers is of both clinical and public health significance(9).

This study was therefore designed to address this gap by rigorously evaluating the effects of daily probiotic-enriched yogurt consumption on metabolic inflammation and lipid profiles in sedentary adults under controlled conditions. The randomized controlled design enables direct comparison with plain yogurt, isolating the specific contribution of probiotic supplementation. The objective of this research is to determine whether regular intake of probiotic yogurt reduces systemic inflammatory markers and

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improves lipid parameters compared to plain yogurt among sedentary adults, thereby elucidating the potential of functional dairy interventions in mitigating metabolic inflammation.

Methods

This randomized controlled trial was implemented to investigate the impact of probiotic-enriched yogurt on markers of metabolic inflammation and lipid levels in sedentary adults from South Punjab. A parallel-group design was employed, wherein subjects were randomly allocated to either an intervention group, which consumed yogurt fortified with probiotics, or a control group, which consumed standard plain yogurt, over twelve weeks. A computer-based randomization sequence ensured balanced group assignment and reduced selection bias. The study maintained blinding of both the participants and the statisticians regarding group allocation to uphold objectivity during the evaluation of outcomes.

The study enrolled healthy, sedentary individuals aged 25 to 45 years who self-reported performing less than 150 minutes of moderate-intensity physical activity weekly. Eligible participants were required to have a body mass index (BMI) ranging from 20.0 to 29.9 kg/m², no prior diagnosis of chronic inflammatory or metabolic disorders, and no consumption of antibiotics or probiotics in the preceding month. Individuals were excluded if they were pregnant or lactating, had diagnosed diabetes, cardiovascular disease, gastrointestinal conditions, or were using any medication known to influence lipid metabolism or inflammatory markers. Recruitment occurred via local health outreach initiatives and community advertisements in the Multan and Bahawalpur districts, with written informed consent secured before participation.

A sample size of 120 participants was determined through a priori power analysis, anticipating a medium effect size (Cohen's d = 0.5) with 80% statistical power and an alpha level of 0.05, while allowing for a 10% attrition rate. The participants were evenly divided into two groups of 60. The intervention group consumed 200 grams of yogurt daily containing *Lactobacillus acidophilus* and *Bifidobacterium bifidum* (with a minimum of 10^8 colony-forming units per serving). The control group received an equivalent portion of non-fortified plain yogurt, matched for sensory and nutritional properties to prevent identification. All participants were directed to take their assigned yogurt with breakfast each day, continue their regular dietary habits, and refrain from any other probiotic or prebiotic supplements for the duration of the study.

Measurements were taken at the start of the trial and after the twelve-week intervention. Primary endpoints were serum concentrations of high-sensitivity C-reactive protein (hs-CRP), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α), analyzed with enzyme-linked immunosorbent assay (ELISA) kits. Secondary endpoints included fasting serum lipid parameters—total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides—assessed using automated biochemical analyzers. Standardized equipment was used to record anthropometric data, including body weight, BMI, and waist circumference. Adherence to the protocol was tracked via weekly follow-ups and inspection of returned yogurt containers.

Statistical analysis was performed using SPSS version 26. Demographic and baseline variables were summarized using descriptive statistics. The normality of data distribution was verified with the Shapiro–Wilk test. Differences between the two groups after the intervention were evaluated using independent samples t-tests. Changes within each group from baseline were analyzed with paired t-tests. Results are presented as mean differences with 95% confidence intervals, and a p-value below 0.05 was considered significant. All data are reported as mean ± standard deviation.

The methodological rigor of the study, including randomized allocation, blinding, and standardized measurements, ensured reliability of findings and minimized bias. The study was designed to generate practical evidence on whether daily probiotic yogurt consumption could effectively attenuate metabolic inflammation and improve lipid parameters in sedentary adults within the South Punjab population.

Results

A total of 120 sedentary adults completed the trial, with 60 participants each in the probiotic yogurt and plain yogurt groups. All participants adhered to the study protocol with a mean compliance rate exceeding 95%, and no adverse events were reported. Both groups were comparable at baseline regarding demographic and anthropometric characteristics (Table 1). The mean age of participants was 33.1 ± 5.2 years, and gender distribution was similar between groups, with a slightly higher proportion of females overall (56%). Baseline BMI and waist circumference values did not differ significantly, indicating homogeneity at study initiation ($p > 0.05$).

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Following twelve weeks of intervention, significant improvements were observed in inflammatory and lipid parameters among participants consuming probiotic yogurt compared to those consuming plain yogurt. Inflammatory markers demonstrated a notable decline in the probiotic group. Mean serum hs-CRP levels reduced from 3.9 ± 1.1 mg/L to 2.4 ± 0.9 mg/L ($p < 0.001$), while IL-6 decreased from 5.6 ± 1.2 pg/mL to 4.1 ± 1.0 pg/mL ($p = 0.002$). Similarly, TNF-α showed a reduction from 7.3 ± 1.4 pg/mL to 6.1 ± 1.2 pg/mL ($p = 0.01$). In contrast, the plain yogurt group showed only marginal and statistically insignificant reductions across all inflammatory markers (Table 2). Between-group comparisons at week twelve confirmed that the probiotic yogurt group exhibited significantly lower inflammatory marker levels ($p < 0.01$ for all parameters).

Lipid profile parameters followed a similar trend. Participants in the probiotic group experienced a decrease in total cholesterol from 201.4 ± 24.5 mg/dL to 184.7 ± 22.1 mg/dL ($p = 0.004$) and LDL cholesterol from 129.6 ± 18.3 mg/dL to 115.3 ± 17.2 mg/dL ($p = 0.002$). HDL cholesterol increased significantly from 43.2 ± 5.6 mg/dL to 47.9 ± 5.8 mg/dL ($p = 0.03$), while triglycerides decreased from 157.9 ± 26.7 mg/dL to 139.5 ± 24.1 mg/dL ($p = 0.01$). The plain yogurt group, however, showed minimal improvements with no statistically significant within-group differences (Table 3).

Anthropometric measures also revealed favorable trends in the probiotic yogurt group, although not reaching strong statistical significance. Mean body weight declined from 75.2 ± 8.7 kg to 74.0 ± 8.5 kg, BMI decreased from 26.1 ± 2.3 to 25.6 ± 2.2 kg/m², and waist circumference reduced modestly from 87.6 ± 6.8 cm to 85.9 ± 6.5 cm. The plain yogurt group displayed negligible changes in these parameters (Table 4).

Overall, Figure 1 illustrates the comparative decline in inflammatory markers across both groups, showing a steeper reduction in hs-CRP and IL-6 among participants receiving probiotic supplementation. Figure 2 depicts the improvement in lipid profiles, highlighting significant increases in HDL and decreases in LDL and triglycerides in the probiotic group relative to controls.

Collectively, these findings demonstrate that daily consumption of probiotic-enriched yogurt for twelve weeks effectively reduced systemic inflammatory markers and improved lipid metabolism in sedentary adults, whereas plain yogurt consumption resulted in minimal changes.

Table 1. Demographic Characteristics of Participants

Variable	Probiotic Yogurt (n=60)	Plain Yogurt (n=60)	p-value
Age (years)	33.2 ± 5.1	32.9 ± 5.3	0.72
Male (%)	43.3	45.0	0.84
Female (%)	56.7	55.0	0.84
BMI (kg/m²)	26.1 ± 2.3	26.3 ± 2.5	0.68
Waist Circumference (cm)	87.6 ± 6.8	88.1 ± 7.2	0.59

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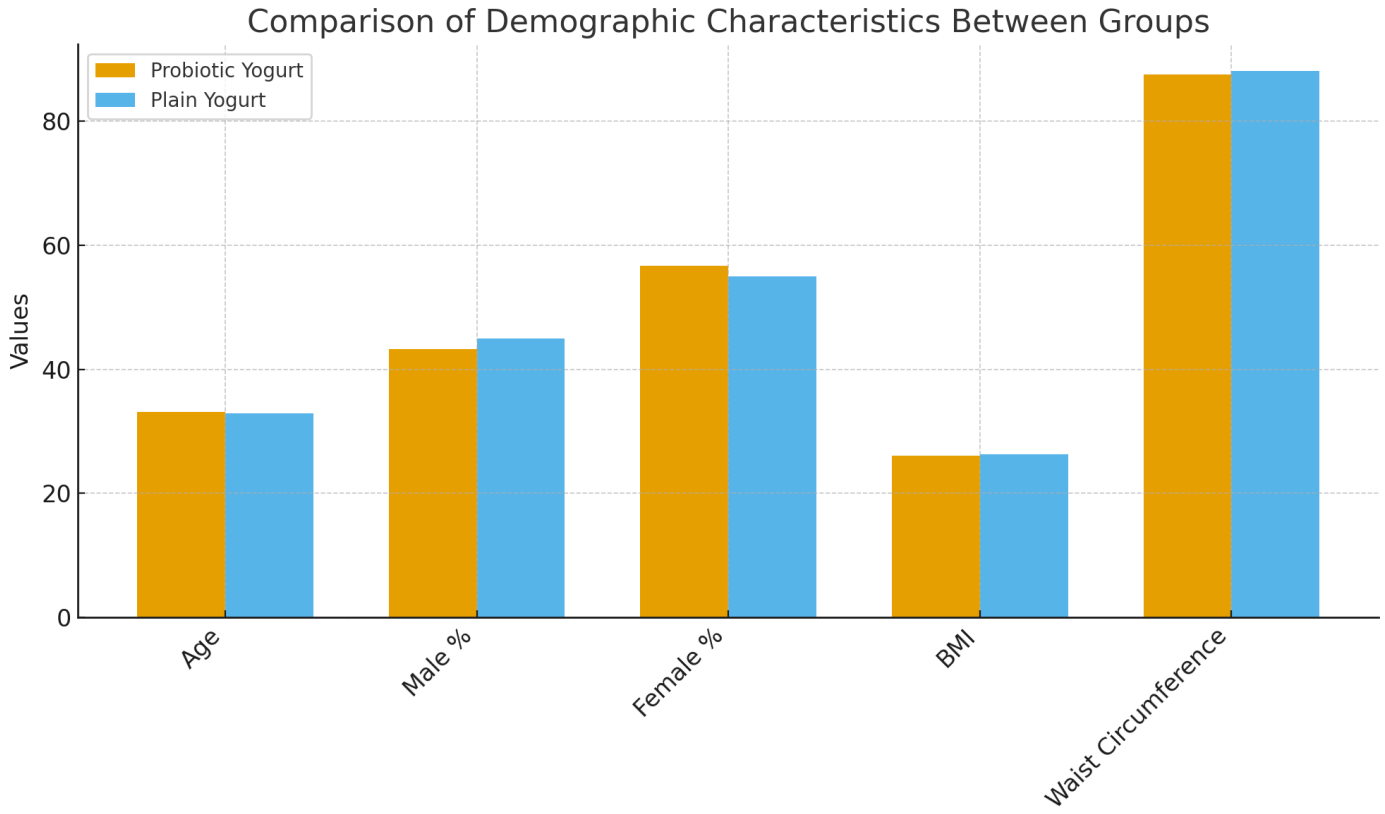

Figure 1 Comparison of Demographic Characteristics Between Groups

Table 2. Changes in Inflammatory Markers

Marker	Baseline (Probiotic)	Post (Probiotic)	Baseline (Plain)	Post (Plain)	p-value (between)
hs-CRP (mg/L)	3.9 ± 1.1	2.4 ± 0.9	3.8 ± 1.0	3.6 ± 1.1	<0.001
IL-6 (pg/mL)	5.6 ± 1.2	4.1 ± 1.0	5.5 ± 1.3	5.3 ± 1.2	0.002
TNF-α (pg/mL)	7.3 ± 1.4	6.1 ± 1.2	7.1 ± 1.5	6.9 ± 1.3	0.01

Table 3. Changes in Lipid Profile Parameters

Parameter	Baseline (Probiotic)	Post (Probiotic)	Baseline (Plain)	Post (Plain)	p-value (between)
Total Cholesterol (mg/dL)	201.4 ± 24.5	184.7 ± 22.1	200.1 ± 25.0	196.5 ± 23.9	0.004
LDL (mg/dL)	129.6 ± 18.3	115.3 ± 17.2	128.1 ± 19.0	125.9 ± 18.7	0.002
HDL (mg/dL)	43.2 ± 5.6	47.9 ± 5.8	43.6 ± 6.1	44.1 ± 5.9	0.03
Triglycerides (mg/dL)	157.9 ± 26.7	139.5 ± 24.1	158.3 ± 27.4	154.7 ± 26.5	0.01

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Table 4. Anthropometric Measurements

Parameter	Baseline (Probiotic)	Post (Probiotic)	Baseline (Plain)	Post (Plain)	p-value (between)
Body Weight (kg)	75.2 8.7	74.0 ± 8.5	75.0 ± 8.4	74.7 ± 8	0.09
BMI (kg/m²)	26.1 ± 2.3	25.6 ± 2.2	26.3 ± 2.5	26.1 ± 2.	0.11
Waist Circumference (cm)	87.6 ± 6.8	85.9 ± 6.5	88.1 ± 7.2	87.8 ± 7.0	0.07

Discussion

This randomized controlled trial assessed the influence of daily probiotic yogurt intake over twelve weeks on indicators of metabolic inflammation and serum lipids in sedentary adults from South Punjab (9). The results revealed that the intervention substantially lowered systemic inflammatory biomarkers—specifically hs-CRP, IL-6, and TNF-α—and favorably altered lipid metabolism by reducing total cholesterol and LDL while raising HDL levels (10). These findings confirm the premise that probiotic intake can positively regulate both inflammatory pathways and metabolic measures in individuals with low physical activity levels (11).

The observed anti-inflammatory effect of probiotic yogurt could be attributed to the action of *Lactobacillus* and *Bifidobacterium* strains, which are known to restore intestinal barrier integrity and suppress systemic endotoxemia. Sedentary behavior, often accompanied by dietary imbalance, promotes gut dysbiosis and increases translocation of microbial endotoxins into the bloodstream, which in turn triggers chronic low-grade inflammation(12). The attenuation of hs-CRP and cytokines in the probiotic group reflected improved gut-immune crosstalk and a possible reduction in intestinal permeability. This finding aligned with previous evidence that probiotics can modulate innate immune pathways, regulate macrophage activation, and influence the production of anti-inflammatory mediators(13).

The lipid-lowering effects observed in this study further reinforced the metabolic potential of probiotic supplementation. A meaningful decline in total cholesterol and LDL levels, along with an increase in HDL, suggested that probiotic strains may alter lipid metabolism through bile salt deconjugation, cholesterol assimilation, and modulation of hepatic lipid synthesis. These mechanisms collectively contribute to improved lipid clearance and reduced plasma cholesterol concentrations(14). The observed improvement in lipid parameters in participants consuming probiotic yogurt, despite the absence of any other dietary or lifestyle modification, underscored the independent metabolic impact of gut microbiota modulation. The plain yogurt group, which did not contain live probiotic cultures, exhibited only minor changes, indicating that the effect was likely strain-specific rather than a general feature of fermented dairy consumption(15).

Although modest reductions were also noted in anthropometric measures such as body weight and waist circumference, these changes were less pronounced than those in biochemical parameters. This finding was consistent with the short study duration and the absence of any structured dietary or physical activity intervention. It nevertheless suggested that probiotic supplementation might indirectly influence body composition through improvements in metabolic efficiency and lipid oxidation. The gradual decline in anthropometric measures could become more substantial over a longer intervention period.

The results carried important implications for preventive health strategies targeting sedentary populations. Given the rising prevalence of metabolic syndrome and related disorders in physically inactive adults, accessible dietary interventions such as probiotic-enriched yogurt may provide a cost-effective means to mitigate inflammation and dyslipidemia before disease onset. The simplicity and cultural acceptability of yogurt make it a suitable vehicle for delivering probiotics in daily routines without requiring major behavioral change. Furthermore, the demonstrated reduction in inflammatory markers signified a potential downstream benefit in reducing long-term cardiometabolic risk.

The strengths of this study included its randomized controlled design, use of standardized biochemical assessments, and focus on a relatively understudied population—healthy sedentary adults who represent a critical stage for preventive interventions. The strict control of confounding factors such as diet, medication use, and probiotic intake enhanced internal validity. Additionally, the inclusion of both inflammatory and lipid markers provided a comprehensive understanding of probiotic effects on metabolic health.

However, several limitations must be acknowledged. The study duration of twelve weeks, while sufficient to observe early metabolic responses, was relatively short for assessing sustained effects or potential long-term benefits. The sample size, although adequate for statistical power, limited subgroup analyses by gender or baseline metabolic status. Dietary intake was self-reported and not monitored through precise caloric measurement, introducing the possibility of unrecognized variations in nutrient consumption. Furthermore, the study employed only two probiotic strains; therefore, the findings cannot be generalized to other formulations or

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dosages. The absence of gut microbiota sequencing restricted mechanistic insight into microbial shifts underlying the observed physiological changes.

Future research should build upon these findings by conducting larger, multicenter trials with extended follow-up to examine the durability of probiotic effects on inflammation and lipid metabolism. Incorporating microbiome analysis would enable a deeper understanding of strain-specific interactions with host metabolic pathways. Combining probiotic supplementation with structured physical activity or dietary modification could further clarify synergistic benefits for cardiometabolic prevention. Studies assessing different probiotic strains, dosages, and delivery formats would also help identify optimal interventions for diverse populations.

In summary, this study provided credible evidence that probiotic-enriched yogurt significantly attenuated metabolic inflammation and improved lipid profiles in sedentary adults compared with plain yogurt. These outcomes supported the role of probiotics as a promising nutritional approach to counteract inflammation and metabolic dysregulation associated with inactivity. While further validation is warranted, the findings highlighted a simple, culturally adaptable, and physiologically meaningful strategy to promote metabolic health in populations at risk of chronic disease.

Conclusion

The study concluded that probiotic-enriched yogurt effectively reduced systemic inflammation and improved lipid metabolism among sedentary adults. Regular consumption for twelve weeks led to significant declines in hs-CRP, IL-6, and LDL levels, alongside increased HDL concentrations. These findings emphasized the potential of probiotics as a simple, accessible, and culturally acceptable dietary intervention to counteract metabolic disturbances associated with physical inactivity, highlighting their value in preventive health strategies targeting early metabolic risk reduction.

AUTHOR CONTRIBUTION

Author	Contribution
Ayesha Ashraf*	Designed the study, performed data collection and analysis, and prepared the manuscript. Approved the final draft for submission.
Abdul Rehman Sarfraz	Contributed to study design, data acquisition, interpretation of findings, and performed critical review and editing of the manuscript. Approved the final draft for submission.
Hina Maqbool	Significantly contributed to data collection and analysis. Reviewed and approved the final manuscript for publication.

References

1. Zolghadrpour M-A, Jowshan M-R, Seyedmahalleh MH, Imani H, Karimpour F, Asghari SJSR. Consumption of a new developed synbiotic yogurt improves oxidative stress status in adults with metabolic syndrome: a randomized controlled clinical trial. 2024;14(1):20333.

2. Park J, Lee Y-S, Lee D-K, Hong J, Park S-J, Lee BW, et al. Effects of a Balanced Diet and Probiotics on Blood Biomarkers and Gut Microbiota in the Elderly: A Community-Based Intervention Study. 2025;17(11):1933.

3. Leziak A, Lipina J, Reclik M, Kocelak PJM. Dietary Modulation of Metabolic Health: From Bioactive Compounds to Personalized Nutrition. 2025;15(9):624.

4. Street ME, Casadei F, Di Bari ER, Ferraboschi F, Montani AG, Shulhai A-M, et al. The Role of Nutraceuticals and Probiotics in Addition to Lifestyle Intervention in the Management of Childhood Obesity—Part 1: Metabolic Changes. 2025;17(10):1630.

5. Koumpouli D, Koumpouli V, Koutelidakis AEJAS. Functional foods, gut microbiome and association with obesity and metabolic syndrome: A literature review. 2024;14(13):5578.

6. López-Yerena A, de Santisteban Villaplana V, Badimon L, Vilahur G, Padro TJN. Probiotics: a potential strategy for preventing and managing cardiovascular disease. 2024;17(1):52.

Submission: 6/Mar/2025
Publication: 30/Mar/2025

7. Sochacka K, Kotowska A, Lachowicz-Wiśniewska SJN. The Role of Gut Microbiota, Nutrition, and Physical Activity in Depression and Obesity—Interdependent Mechanisms/Co-Occurrence. 2024;16(7):1039.

8. Ambroselli D, Masciulli F, Romano E, Catanzaro G, Besharat ZM, Massari MC, et al. New advances in metabolic syndrome, from prevention to treatment: the role of diet and food. 2023;15(3):640.

9. Britos S, González AF, Flax Marcó F, Katz M, Schuldberg J, Torresani ME, et al. Yogurt, in the context of a healthy diet, for the prevention and management of diabetes and obesity: a perspective from Argentina. 2024;11:1373551.

10. Okoye CC. Yogurt Consumption and Exercise Improve Immunological Factors in Lactating Women: North Carolina Agricultural and Technical State University; 2024.

11. Maqsood S, Asif M, Alvi T, Shakoor S, Zahir AJJoD, Disorders M. Probiotics and functional foods in metabolic disease: emerging solutions for obesity and diabetes. 2025;24(2):185.

12. Perrone P, D'Angelo SJN. Gut microbiota modulation through Mediterranean diet foods: implications for human health. 2025;17(6):948.

13. Khan S, Ahmad F, Khalid NJMN, Research F. Applications of Strain-Specific Probiotics in the Management of Cardiovascular Diseases: A Systemic Review. 2024;68(8):2300675.

14. Jang H, Joung H, Chu J, Cho M, Kim Y-W, Kim KH, et al. Lactobacillus delbrueckii subsp. lactis CKDB001 ameliorates metabolic complications in high-fat diet-induced obese mice. 2024;16(24):4260.

15. Nesci A, Carnuccio C, Ruggieri V, D'Alessandro A, Di Giorgio A, Santoro L, et al. Gut microbiota and cardiovascular disease: evidence on the metabolic and inflammatory background of a complex relationship. 2023;24(10):9087.

16. Liu Y, Hu Y, Ma B, Wang Z, Wei BJME. Gut microbiota and exercise: probiotics to modify the composition and roles of the gut microbiota in the context of 3P medicine. 2025;88(1):1-18.

17. Barrea L, Verde L, Auriemma RS, Vetrani C, Cataldi M, Frias-Toral E, et al. Probiotics and prebiotics: any role in menopause-related diseases? 2023;12(1):83-97.

18. El Hage R, Al-Arawe N, Hinterseher IJIJoMS. The role of the gut microbiome and trimethylamine oxide in atherosclerosis and age-related disease. 2023;24(3):2399.

19. Garcia-Gutierrez E, O'Mahony AK, Dos Santos RS, Marroquí L, Cotter PDJGM. Gut microbial metabolic signatures in diabetes mellitus and potential preventive and therapeutic applications. 2024;16(1):2401654.

20. Charitos IA, Colella M, Carretta DM, Santacroce LJSM, Science H. Probiotics, gut microbiota and physical activity: A close relationship. 2025.

21. Qi Y, Wang XJN. The role of gut microbiota in high-fat-diet-induced diabetes: lessons from animal models and humans. 2023;15(4):922.

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