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Effect of Leisure Walking on Biochemical Parameters in Patients with Type II Diabetes Mellitus

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ABSTRACT

OBJECTIVE: To evaluate the impact of a leisure walking program on biochemical and hematological parameters of Type 2 Diabetes mellitus patients in Hyderabad, Sindh.

METHODOLOGY: It is a quasi-experimental, single-group, longitudinal study conducted from September 2023 to August 2025, using convenience sampling. 40 individuals (male and female) aged 30 to 60 years with only Type 2 Diabetes mellitus (T2DM) participated in the study and were exposed to a supervised home-based walking program for 9 months. The intervention consisted of moderate-intensity aerobic exercise (50-70% of maximal heart rate), performed by walking at 3-4mph for over 15 minutes a day, 7 days a week, excluding warm-up and cool-down. Assessment has been carried out at 4 time points (baseline, 3, 6, and 9 months) for biochemical parameters (HbA1c, FBS, RBS, T.G, total lipids, cholesterol, HDL, LDL) and hematological parameters (hematocrit, Hemoglobin, platelet count, WBC, ESR). Repeated-measures ANOVA, paired t-tests, Friedman, and Wilcoxon signed-rank tests have been used to analyze data in the R programming environment. 4.4.1 and Python version. 3.12.

RESULTS: There have been pronounced changes in glycemic control. Total cholesterol, TG, LDL and VLDL decreased, whereas HDL and Hemoglobin increased remarkably after 9 months of walking. ESR also decreased, indicating that inflammation decreased.

CONCLUSION: A structured, moderate-intensity walking program has been shown to have a significant positive effect on biochemical and hematological parameters of T2DM patients. Walking is a useful, low-cost adjunct in scarce-resource environments.

KEYWORDS: Type II Diabetes Mellitus, Walking Program, Glycemic Control, Lipid Profile, Hematological Parameters, HbA1c.

INTRODUCTION

Type II Diabetes Mellitus (T2DM) is a chronic metabolic disease, manifested by insulin resistance and progressive dysfunction of beta cells leading to chronic hyperglycemia and long-term complications of multiple organ systems[1]. The disease is a major cause of morbidity and mortality worldwide, being linked with microvascular (retinopathy, nephropathy, neuropathy) and macrovascular complications (cardiovascular disease and stroke)[2]. The prevalence of T2DM worldwide has risen dramatically over the last few decades, driven by demographic transitions, dietary changes, urbanization, and sedentary lifestyles[3]. Approximately 537 million adults are currently living with diabetes globally, and projections estimate an increase in this figure to 783 million by 2045[2]. Irony is that the burden is disproportionately concentrated in low and middle-income countries, where lack of preventative services and delayed diagnoses compound morbidity and mortality[3]. In Pakistan, the diabetes epidemic is a critical public health issue. National Diabetes Survey of Pakistan (2016-17) reported 26.3million adults have diabetes, with a substantial proportion remain undiagnosed[4]. Recent analyses highlight a prevalence of 11.77% at the national level, with a higher rate in males in urban areas. While in Sindh province, prevalence is reported to be as high as 16.2% in males and 11.7% in females[5]. Poor glycemic control is common in Pakistan, with reviews showing that patients do not attain glycemic goals and are at high risk of complications, i.e. nephropathy, retinopathy and other microvascular pathologies[6]. Given its multifactorial etiology, management of T2DM should be based on a comprehensive approach combining pharmacological and lifestyle interventions. Physical activity plays a central role, with strong evidence that regular aerobic exercise improves insulin sensitivity, promotes glycemic control, and produces favorable changes in lipid metabolism and body composition[7]. Walking, in particular, is an effective intervention when applied within a resource-limited context, is culturally acceptable, and is applicable at a wide scale[8]. Meta-analyses and systematic reviews have confirmed significant reductions in HbA1c, BMI, and blood pressure in patients with T2DM following walking interventions[9-11]. Therefore, there is a need to assess the efficacy of walking as a feasible, less resource-consuming, and non-pharmacologic approach to improve glycemic control and biochemical and hematological parameters in diabetic patients.

METHODOLOGY

Study Design

A quasi-experimental, single-group, longitudinal pre-post intervention study was conducted from September 2023 to August 2025. 40 subjects (male and female, aged 30-60 years, with only T2DM) were included in the study, whereas participants with other disorders were excluded. Subjects were from various parts of Hyderabad, Sindh, and were recruited through convenience sampling. The Ethical Committee, Institute of Biochemistry, University of Sindh, Jamshoro, approved the study vide Reference No. IOB/329/2023, dated 31-05-2023. Informed consent was obtained from all participants. Statistical analysis has been done with repeated-measures comparisons. The study included repeated measures meant to measure the impacts of a structured walking program on the biochemical and hematological measures in patients of T2DM.

Laboratory Parameters

Biochemical parameters included Triglycerides (T.G), Total Lipid, Cholesterol, High-density lipoprotein (HDL), Low-density lipoprotein (LDL), Fasting Blood Sugar (FBS), Random Blood Sugar (RBS) and Glycated Hemoglobin (HbA1c). Hematological parameters, including Hematocrit, Platelet Count, White Blood Cells (WBC), Hemoglobin, and Erythrocyte Sedimentation Rate (ESR). Measurements have been assessed at four different stages: baseline (before walking), after 3, 6, and 9 months. Comparisons were drawn between these time periods. Inter-individual variation was minimized by having each participant act as their own control.

Intervention: Walking Program

All participants were engaged in a moderate-intensity walk session (monitored home-based) for 15 minutes every morning for seven days a week with a 5-10 minute warm-up, and a 5-minute cool-down. The desired intensity was 50-70 percent of the maximal heart rate(in most cases walk@3-4mph, and fit individuals did brisk walk @4-5mph). Heart rate monitors and perceived exertion instructions were provided to facilitate target intensity.

Specimen Collection and Laboratory Procedures

Gel (serum) and EDTA tubes were used to collect venous blood samples from the trained phlebotomists using aseptic procedures. Samples were subjected to routine testing: EDTA samples and complete blood count (CBC) on an XN-350 automated hematology analyzer, which provided six-part differentials and CBC indices. Serum samples: the separated samples were centrifuged and used for biochemical tests, including HbA1c, FBS, RBS, and lipid profile. Analysis was performed on the Roche Cobas C111 analyzer using photometric and enzymatic methods. Calibration and quality control: Standard operating procedures were used, including the use of manufacturer-supplied calibrators and running of daily quality control with normal and pathological controls. Reviewing of results was done before reporting.

Statistical analysis

Data Analysis has been done using the software R version 4.4.1 and Python 3.12. Normality of continuous variables has been evaluated by the Shapiro-Wilk test, which was justified by the visualization of histograms and Q-Q plots. Based on the results, variables were categorized as either parametric or nonparametric[12]. Descriptive statistics of both groups were computed, and boxplots of the distributions were drawn. In dependent-samples designs, a paired t-test was used to compare two time points when data were normally distributed[13,14], and a repeated-measures ANOVA was used to compare when data had more than three time points[13,15]. of nonparametric data, the Wilcoxon signed-rank test was applied to two dependent samples[13,16], and the Friedman test was applied when there were three or more dependent samples[13]. The baseline (before walking program) and after 3 months, after 6 months and after 9 months have been subjects of comparison. A p-value of below 0.05 was taken to be significantly relevant.

RESULTS

Descriptive Statistics

As shown in **Table Ia & Ib**, Normal descriptive: T.G, hematocrit, platelet count, and WBC count: There has been a normal distribution of T.G, hematocrit, platelet count, and WBC count over the period of study, as shown by p-values (<0.05). During the first month before walking intervention (Month 1) to Month 3, 6, and 9 after walking, the mean of T.G increased gradually and steadily, indicating that levels of T.G of both mean and median type showed the same pattern, which was a gradual decrease, with the variability remaining comparatively constant, indicating a similar effect on all participants. The increase in hematocrit was gradual over the same period, as shown by the increased mean and median, and there was uniform dispersion, indicating that red blood cell concentration improved across all groups. There was a slight downward movement in platelet counts, with slight changes in mean and median values and constant variability, which is an indication of a small but steady decline. The number of WBC shows a progressive decrease over time, as indicated by a decreasing central tendency and relatively constant dispersion, suggesting a consistent drop in the level of immune cells among subjects. Comprehensively, these results suggest that walking produced a pattern of consistent physiological alterations throughout the course of the study, directional tendencies in lipid profile, hematological measures, and the number of immune cells, and mostly similar responses among the groups. Non-normal descriptive: HbA1c, FBS, RBS, total lipids, total cholesterol, HDL cholesterol, LDL cholesterol, Hemoglobin, and ESR were non-normally distributed across the study period, as reflected in p-values < 0.05. After walking intervention, the trends in HbA1c, FBS, and RBS showed a clear, consistent downward trend during 3, 6, and 9 months after baseline, which showed an upward trend, and median values decreased over time among participants, demonstrating improved level of glycemic control. Total lipid and total cholesterol levels also decreased steadily during the study period, whereas HDL cholesterol increased steadily, indicating a positive change in the lipid profile. There was a gradual reduction in LDL cholesterol, which supports a positive effect on cardiovascular risk factors. The level of Hemoglobin slightly improved over time, providing evidence of a slight improvement in red blood cells. ESR continued to decrease, indicating a decrease of systemic inflammation. In all, these variables, values of central tendency were moving towards the expected direction, and the dispersion was relatively steady, indicating that walking intervention had produced the same physiological responses across all the participants, and the responses have been positive in terms of glycemic control, lipid metabolism, hematological parameters and the inflammatory condition.

Table Ia: Descriptive statistics and normality assessment (Shapiro–Wilk test)

Normal Variable	Mean±SD	p-value
T.G (<150mg/dl) *Baseline	296±20.07	0.305
After 3 months	285.6±19.22	0.203
After 6 months	271.87±17.74	0.155
After 9 months	254.25±18.45	0.334
HEMATOCRIT (36-50%) *Baseline	38.94±4.0	0.384
After 3 months	41.10±3.91	0.600
After 6 months	42.77±4.02	0.231
After 9 months	44.65±4.05	0.344
PLAT COUNT (150-450 10^9/L)*Baseline	401.47±52.06	0.705

After 3 months	390.9±51.79	0.785
After 6 months	381.65±51.80	0.767
After 9 months	378.35±49.48	0.554
WBC (4.5-11.0 10^9/L) *Baseline	13.09±1.107	0.135
After 3 months	12.68±1.107	0.058
After 6 months	12.105±1.118	0.178
After 9 months	11.55±1.135	0.052

Note: Normal variables: variables following a normal distribution (Shapiro–Wilk test).
**Baseline; before start of walk program*

Table Ib: Descriptive statistics and normality assessment (Shapiro–Wilk test)

Non-normal Variable	Mean	p-value
HbA1c (<5.7%) *Baseline	11.24±1.44	0.045
After 3 months	10.14±1.36	0.003
After 6 months	9.36±1.186	0.000
After 9 months	8.40±1.190	0.000
FBS (77-99mg/dl) *Baseline	164±15.56	0.008
After 3 months	160.47±13.90	0.040
After 6 months	156.82±13.89	0.027
After 9 months	152.77±13.85	0.029
RBS (<140 smg/dl) *Baseline	365.12±31.11	0.002
After 3 months	360.15±30.50	0.002
After 6 months	355.55±31.00	0.002
After 9 months	347.87±30.18	0.010
TOTAL LIPID (<200 mg/dl)*Baseline	919.12±37.88	0.015
After 3 months	913.07±34.62	0.006
After 6 months	882.5±31.94	0.044
After 9 months	862.25±32.30	0.014
CHOLESTROL (<200 mg/dl)*Baseline	341.4±39.29	0.000
After 3 months	352.02±26.93	0.000
After 6 months	318.87±26.59	0.031
After 9 months	236.95±29.73	0.029
HDL (35-60 mg/dl) *Baseline	23.6±5.18	0.000
After 3 months	27.95±4.88	0.001
After 6 months	32.17±4.44	0.000
After 9 months	37.87±4.11	0.032
LDL (<100mg/dl) *Baseline	158.63±16.46	0.000
After 3 months	152.9±16.33	0.000
After 6 months	144.63±18.17	0.023
After 9 months	132.49±16.92	0.028
HEMOGLOBIN (13-16g/dl) *Baseline	10.16±0.65	0.008
After 3 months	10.4±0.63	0.015
After 6 months	10.59±0.63	0.021
After 9 months	10.86±0.59	0.018
ESR (<20mm/hr) *Baseline	55.27±14.89	0.048
After 3 months	52.37±14.20	0.021
After 6 months	49.65±14.13	0.006
After 9 months	45.97±13.38	0.003

Note: Non-normal variables: variables not following a normal distribution
**Baseline; before start of walk program*

Boxplots of Normally Distributed Variables

Figure 1: Boxplots of normally distributed variables showed significant temporal changes between baseline and follow-ups (3, 6, and 9 months), which were confirmed using repeated-measures ANOVA ($p<0.001$ for all variables). At baseline, T.G was high, and progressive decreases in median values with diminished variability at 9 months indicated a steady improvement of lipid metabolism. The values of hematocrit demonstrated a consistent upward trend with the follow-up period, indicating an increase in oxygen-carrying capacity and hematological state; however, the interquartile ranges have been relatively narrow, which can be ascribed to personal variation. The platelet count, which was relatively high at baseline, increased early between 6 and 9 months, after which it stabilized. This trend indicated an initial rise in platelet activity, which did not increase further. On the same note, the number of WBC progressively decreased from baseline to 9 months, which relates to a decline in systemic immune and inflammatory responses. Taken together, the identified changes in central tendency and variability, validated by extremely significant ANOVA values, highlight the positive influence of walking on lipid, hematological, and immunological values over time.

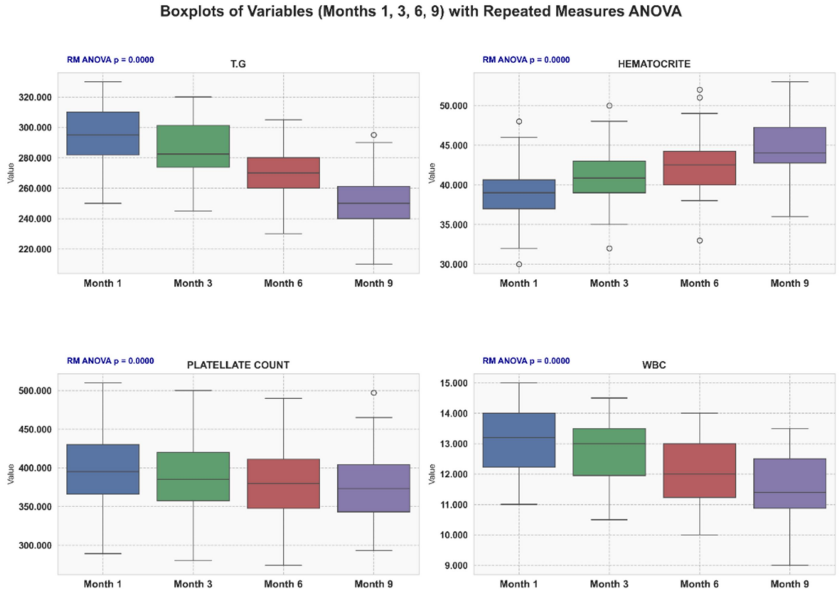

Figure 1: Boxplots of normally distributed variables analyzed with repeated-measures ANOVA

Boxplots of Non-Normally Distributed Variables

Figure 2 Shows that boxplot analysis revealed that glycemic, lipid, hematological, and inflammatory parameters improved significantly after the walking intervention, as confirmed by the Friedman test ($p < 0.001$ of all parameters). Baseline-elevated HbA1c and RBS exhibited progressive changes with a negative median and a reduced inter-quartile range at 3, 6 and 9 months, which demonstrated long- and short-term glycemic control improvements. The lipid parameters had a positive trend. There was an identical reduction in the median of total lipids and LDL, with decreased variation, and an upward trend in HDL, which was low at baseline and then increased, indicating an improvement in cardio protective lipid fractions coupled with a very slight increase in dispersion among respondents. There was also a general downward trend of total cholesterol (TC). Median did not change significantly between baseline and three months, but distinct downward changes were observed between three and six months and were sustained until nine months, so the most significant changes

occurred after the first three months of intervention. Hemoglobin showed a slow increase in median values, indicating improvement in hematological condition. Still, ESR, which had initially been high, showed a negative trend and decreased variability, indicating a decrease in systemic inflammation. Taken as a whole, boxplots depict consistent and clinically significant benefits of regular walking, and the Friedman analysis, which supports the statistical validity, stresses the strength of the temporal changes.

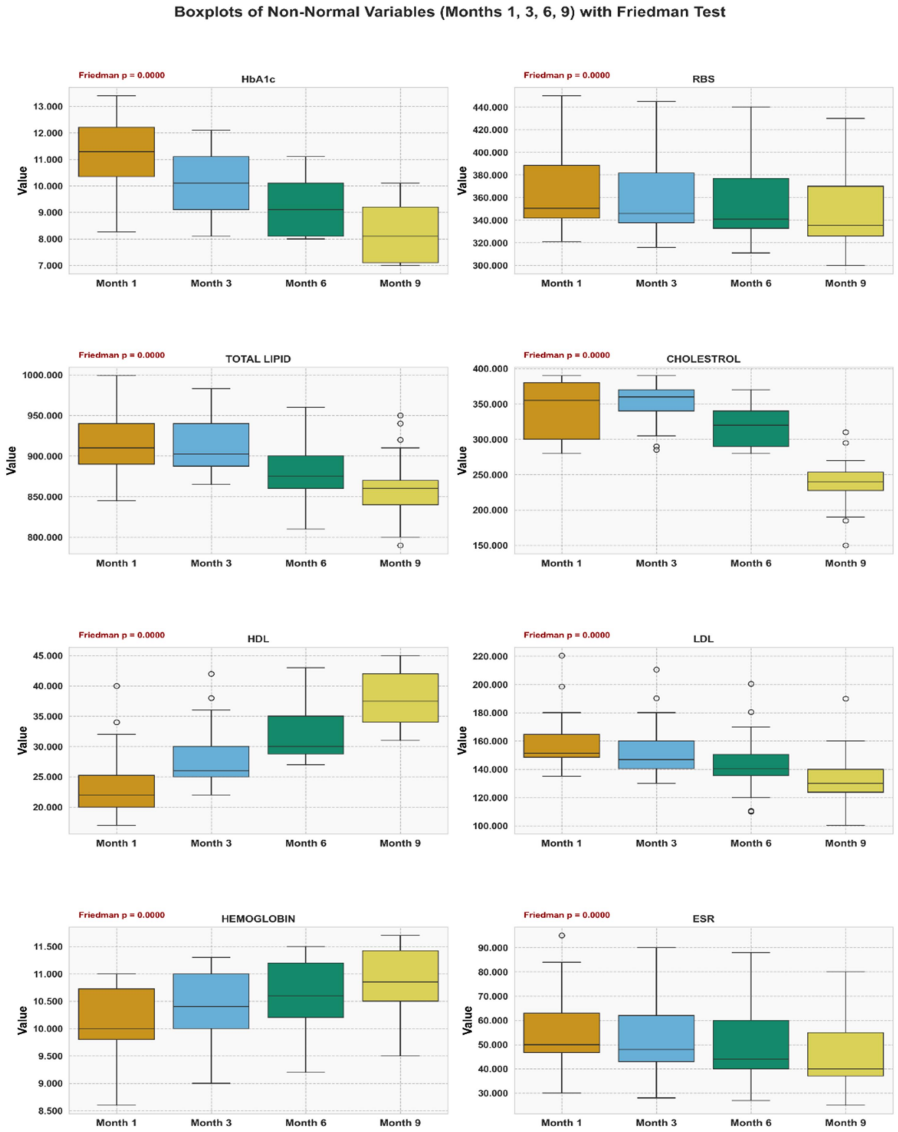

Figure 2: Boxplots of non-normally distributed variables analyzed with the Friedman Test

Tests Interpretation of Normally Distributed Variables

In **Table II,** T.G indicates a steady and significant decrease during the intervention period. The repeated-measures ANOVA shows the existence of an overall effect ($F=178.823$, $p<0.05$); paired t-tests show a significant decrease from baseline at 3, 6, and 9 months (all $p<0.05$). The hematocrit (HCT) gradually increased throughout the course of the study. Repeated-measures ANOVA showed that the overall effect was significant ($F=215.270$, $p<0.05$), and the gain was significant of each follow-up interval on a paired t-test (all

p<0.05). The overall change in the platelet count (PLT) was significant (F=25.450, p<0.05). Paired t-tests showed significant differences between baseline and three months and three and six months (both p<0.05). There was no significant difference after six and nine months (p=0.412). WBC showed a significant, steady positive trend (F=620.956, p<0.05). Paired t-tests showed a significant change in baseline and three months, three to six months, and six-9 months (all p<0.05).

Table II: Analysis of normally distributed variables using paired t-test and repeated-measures ANOVA

Variables	**T.G (mg/dl)**				**HEMATOCRIT (%)**			
	RM	Paired T-Test			RM	Paired T-Test		
Test	ANOVA	1 vs 3	3 vs 6	6 vs 9	ANOVA	1 vs 3	3 vs 6	6 vs 9
Statistic	178.823	6.657	8.103	10.265	215.27	-8.547	-14.601	-13.437
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Variables	PLATELLATE COUNT(10⁹/L)				WBC(10⁹/L)			
	RM	Paired T-Test			RM	Paired T-Test		
Test	ANOVA	1 vs 3	3 vs 6	6 vs 9	ANOVA	1 vs 3	3 vs 6	6 vs 9
Statistic	25.450	13.757	20.313	0.830	620.956	15.576	14.633	15.832
p-value	0.000	0.000	0.000	0.412	0.000	0.000	0.000	0.000

Test Results (Non-Normally Distributed Variables)

Table III: HbA1c showed a significant decrease during the intervention period. The Friedman test showed that the effect was overall (χ^2=115.52, p<0.05). Wilcoxon signed-rank tests showed significant reductions from baseline to three months, three to six months, and six to nine months (all p<0.05). RBS also reduced significantly over time. The Friedman test showed that the change was highly significant (χ^2 = 116.76, p < 0.05). The pairwise comparisons of the Wilcoxon test showed significant differences between baseline and three months (p<0.05), three months and six months (p<0.05), and six months and nine months (p<0.05). The total lipids (TL) showed a progressive reduction over the 9-month intervention, with the overall effect found to be significant (χ2 = 113.88, p < 0.05). Wilcoxon tests were used to ensure that stepwise reductions were significant (all p-values < 0.05). A significant overall decrease in total cholesterol (TC) was observed (χ^2=92.59, p<0.05). But no difference was noted between baseline and 3 months (p=0.54). There were significant changes observed at three to six months and six to nine months (both p<0.05). The level of HDL was significantly elevated during the intervention (χ^2=120, p<0.05). Wilcoxon tests showed that the rises at three, six, and nine months were highly significant compared with baseline (all p<0.05). There was a significant and consistent decrease in LDL (χ^2 = 107.58, p < 0.05). Significant differences between baseline and three months, three and six months, and six and 9 months were observed using pairwise Wilcoxon tests (all p<0.05). Hemoglobin (Hb) values increased gradually throughout the study period. Results of the Friedman test showed that the overall effect was significant (χ^2=120, p<0.05), and the Wilcoxon tests showed significant gains at all follow-up intervals (all p<0.05). There was a significant decrease in ESR in the course of the intervention (χ^2=116.49, p<0.05). Significant reductions were observed between the three-month, six-month, and nine-month time points (all p<0.05) using Wilcoxon tests.

Table III: Analysis of non-normally distributed variables using the Wilcoxon signed-rank test and the Friedman test

Variable	**HbA1c (%)**				**RBS (mg/dl)**			
Test	Wilcoxon			Friedman Test	Wilcoxon			Friedman Test
	1 vs 3	3 vs 6	6 vs 9		1 vs 3	3 vs 6	6 vs 9	
Statistic	0.000	0.00	0.00	115.51	8.000	0.000	1.000	116.76
p-value	0.000	0.00	0.00	0.000	0.000	0.000	0.000	0.000
Variable	TOTAL LIPID (mg/dl)				CHOLESTROL (mg/dl)			
Test	Wilcoxon			Friedman Test	Wilcoxon			Friedman Test
	1 vs 3	3 vs 6	6 vs 9		1 vs 3	3 vs 6	6 vs 9	
Statistic	193.0	0.00	0.00	113.88	365.00	0.000	1.000	92.592
p-value	0.003	0.00	0.00	0.000	0.543	0.000	0.000	0.000
Variable	HDL (mg/dl)				LDL (mg/dl)			
Test	Wilcoxon			Friedman Test	Wilcoxon			Friedman Test
	1 vs 3	3 vs 6	6 vs 9		1 vs 3	3 vs 6	6 vs 9	
Statistic	0.000	0.00	0.00	120.00	5.00	40.00	0.000	107.578
p-value	0.000	0.00	0.00	0.000	0.00	0.00	0.000	0.000
Variable	HEMOGLOBIN (g/dl)				ESR(mm/hr)			
Test	Wilcoxon			Friedman Test	Wilcoxon			Friedman Test
	1 vs 3	3 vs 6	6 vs 9		1 vs 3	3 vs 6	6 vs9	
Statistic	0.000	0.00	0.00	120.00	29.500	0.000	0.000	116.49
p-value	0.000	0.00	0.00	0.000	0.000	0.000	0.000	0.000

DISCUSSION

This research revealed that a systematic walking intervention of nine months led to statistically significant and clinically meaningful changes in the biochemical and hematological indicators in patients of T2DM. Consistency of positive changes was reported in both parametric (repeated-measures ANOVA, paired t-tests) and nonparametric analyses (Friedman and Wilcoxon signed-rank tests), which highlight the strength of the results. Glycemic Parameters: Glycemic control significantly improved, as shown by a steady decrease in HbA1c (χ^2=115.52, P<0.05) and RBS (χ^2=116.76, P<0.05) at all times. HbA1c is an indicator of long-term glycemic control, and a gradual decrease of the parameter indicates long-term positive outcome of walking in enhancing insulin sensitivity and peripheral uptake of glucose[7]. Enhancements in RBS also represent the acute exercise effect on glycemic balance. These results are corroborated by previous evidence that aerobic exercises, such as walking, lower HbA1c by a significant margin in T2DM patients in Pakistan[9].Of relevance to a population health approach, these figures are very worrying in Pakistan, where an astounding number of individuals with T2DM are not adequately controlled[6]. Community-based walking interventions can help stabilize the burden of uncontrolled diabetes and its complications. Lipid Profile: Lipid profile showed good changes. The T.G (F=178.823, p<0.05), total lipids (χ2=113.88, p< 0.05), and LDL cholesterol (χ2=107.58, p< 0.05) significantly decreased, whereas the HDL cholesterol significantly increased (χ^2=120, p=0.05). Lipid benefits were not observed until 6 months (χ^2=92.59, p<0.05), indicating that the benefits of long-term intervention may take time. The findings are consistent with previous findings that exercise improves lipid metabolism by increasing the oxidation of fatty acid oxidation and the activities of lipoprotein enzymes[8,17,18]. Since dyslipidemia is a significant risk factor in cardiovascular conditions of diabetic populations, identified changes have high clinical value, especially in low-resource settings, where the availability of lipid-lowering medications is scarce[2].

Hematological Parameters: The walking program had a significant effect on hematological indicators. The rate of increase in hematocrit (F=215.270, p<0.05) was accompanied by gains in Hemoglobin (χ^2=120, p<0.05), which is consistent with stimulation of erythropoiesis and an increase in oxygen-carrying capacity, as a result of exercise[19]. The number of platelets increased in the first six months (F=25.450, p<0.05) and then levelled off (p=0.412), reflecting an early adaptive mechanism and then homeostasis. WBC count showed a steady increase (F=620.956, p<0.05), consistent with exercise-induced leukocytosis, typically viewed as the mobilization of immune cells rather than pathologic inflammation[19,20]. These hematologic changes could enhance tissue oxygenation and the immune response, which are essential of alleviating the complications associated with diabetes. Inflammatory Marker: The large decrease in ESR (χ^2=116.49, p<0.05) suggests anti-inflammatory effects of walking. The decrease in ESR thus indicated that walking is more than a metabolic intervention; it is an anti-inflammatory intervention in the management of diabetes.

Statistical and Public Health Significance: The statistical integrity of the results based on the finding of a consistent significance of the results of various tests (p<0.05) indicates that the effects of the interventions were not a result of randomness. In medicine, the risk of micro and macro-vascular complications (retinopathy, nephropathy, neuropathy, stroke, and myocardial infarction) is reduced by improving glycemic, lipid, hematological, and inflammatory parameters[1]. The health impacts are significant to the population, since Pakistan has one of the highest burdens of diabetes in the world[4,5]. Walking is a more affordable and culturally accessible intervention that can be diversified through community health programs, workplace health programs, and gender-sensitive campaigns, making it an effective alternative in environments with limited resources.

CONCLUSION

This research indicates that a well-designed walking program of 9 months has significant and progressive improvement in key bio-parameters. Significant reductions have been observed in HbA1c, FBS, and RBS, indicating a meaningful improvement in glycemic control. Initial analysis of the Walking Group also showed positive results in Lipid Profile parameters, including significant reductions in Total Cholesterol, Triglycerides, and LDL, and a marked increase in HDL. Improvements in Hematological Parameters have been noted, such as a steady rise in Hemoglobin and a decrease in ESR, reflecting reduced systemic inflammation over time. Overall, the structured walking intervention is confirmed as an effective, low-cost, and sustainable non-pharmacological strategy for achieving meaningful overall health improvements in patients with Type II Diabetes Mellitus, particularly in a resource-limited context.

Disclaimer: This work is from the PhD thesis of Ms. Mahak Memon (1st Author of this article)

Ethical Permission: Institute of Biochemistry, University of Sindh, Jamshoro, Pakistan, IRB approval letter No. IOB/329/2023.

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Data Sharing Statement: The corresponding Author can provide the data proving the findings of this study on request. Privacy or ethical restrictions bound us from sharing the data publicly.

AUTHOR CONTRIBUTION

Memon M: Data collection, Literature search, Analysis and interpretation
Shah A: Study Design, Drafting, Data Interpretation.
Memon FN: Literature search, Data collection

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