

The Impact of Structured Physical Activity on Glycemic Control and Metabolic Outcomes in Patients with Type 2 Diabetes: A Randomized Controlled Trial

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ABSTRACT

Background: Type-2 diabetes is a major health challenge, requiring effective interventions for glycemic and metabolic control. Structured physical activity offers a promising non-pharmacological approach to improving these outcomes.

Objectives: The objective of this study was to evaluate the effects of structured physical activity on glycemic control and metabolic outcomes in patients with Type-2 diabetes (T2D).

Methods: This randomized controlled trial included 200 adult patients with T2D, randomly assigned to one of three groups: structured exercise once a week, thrice a week or usual care. Participants followed for 6 months and exercise interventions were combined aerobic and resistance training. Hemoglobin A1c (HbA1c) and fasting glucose the primary while Body mass index (BMI), waist circumference and lipid profiles were secondary outcomes

Results: HbA1c was reduced significantly more in the thrice-weekly exercise group (-0.38%, $p = 0.005$) than in the once week group (-0.16%, $p > 0.05$) or control group. Changes in the once weekly group were not significant, whereas the thrice weekly group's fasting glucose levels improved significantly (-0.25%, $p < 0.05$). BMI and lipid profile improvements were also more pronounced in the thrice weekly group with greater reductions in total cholesterol and LDL cholesterol compared to other groups.

Conclusion: Thrice-weekly structured exercise significantly improves glycemic control and metabolic outcomes in T2D compared to once-weekly regimens, highlighting the importance of exercise frequency. Future research should focus on strategies to enhance adherence to frequent exercise programs.

Keywords: Type-2 diabetes, glycemic control, physical activity, structured exercise, HbA1c, fasting glucose, metabolic outcomes, aerobic exercise, resistance training, randomized controlled trial (RCT).



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INTRODUCTION

Type-2 diabetes (T2D) is an increasing global health emergency; today affecting more than 463 million people, with numbers predicted to increase in the coming decades[1]. Persistence of hyperglycemia, in the context of insulin resistance and progressive decline of pancreatic β -cell function, defines T2D. T2D, if left untreated or poorly managed, can lead to serious complications, including cardiovascular disease, nephropathy, neuropathy, and retinopathy, which together account for high morbidity and

mortality rates worldwide. The direct impact on health and the economic burden that T2D imposes on healthcare systems is the result of the high costs of its management and treatment of its complications[2]. The cornerstone of T2D management includes lifestyle interventions, mostly diet and physical activity. Regular physical activity improves insulin sensitivity, enhancing glucose uptake in skeletal muscles, and improves overall metabolic health. Underlying strong evidence of exercise as an effective intervention for glycemic control, there is considerable

debate as to the best frequency, intensity and type of exercise that will lead to the best T2D outcomes[3]. Research done previously has shown that both aerobic and resistance exercise have benefits as aerobic exercise improves cardiovascular fitness and insulin sensitivity and resistance training increases muscle mass and glucose disposal. Modality combined exercise regimens have even more benefits in glycemic control and metabolic health. Although the frequency of exercise sessions needed to achieve optimal results in real world settings has not been extensively studied[4]. Organizations like the American Diabetes Association currently recommend at least 150 minutes of moderate intensity aerobic activity per week in addition to resistance training on two or more days. Although supported by clinical trials, adherence in the general population is poor[5]. However, many people with T2D have difficulty with regular physical activity, and the effects of different exercise frequencies on glycemic and metabolic outcomes in routine clinical practice are not well known[6]. To fill this gap, we designed a study to examine the impact of once weekly versus three weekly structured physical activity on glycemic control and metabolic outcomes in patients with T2D[7]. We postulated that patients who completed thrice weekly structured exercise sessions would show better improvements in HbA1c, fasting glucose, BMI, and other metabolic parameters than those in the once weekly or control groups. These findings have potential implications for refining exercise recommendations and developing optimized strategies for long term management of T2D[8].

MATERIALS AND METHODS

A randomized controlled trial (RCT) was designed to test the effect of structured physical activity on glycemic control and metabolic outcomes in patients with type- 2 diabetes (T2D). The study was conducted over six months February 2024 till July 2024 at Ghurki trust & teaching hospital Lahore, Pakistan. With participants randomly assigned to one of three groups. structured exercise once a week, structured exercise three times a week, or usual care (control group). The study was conducted according to the CONSORT guidelines for RCTs and was approved by the institutional review board prior to participant recruitment. The study population included adult patients 25 to 70 years of age with T2D and baseline HbA1c values between 6.5% and 13%. Inclusion was any patients who were not using insulin for glycemic control and were able to get involved in exercise. Severe comorbid conditions, including cardiovascular disease, uncontrolled hypertension, or any other conditions which would preclude safe participation in an exercise program, were exclusion criteria. They also excluded patients who had had a recent hospitalization, and those who were pregnant. Before enrollment, all participants provided written informed consent. According to computer-generated schedule all the participants were randomized in three groups, structured exercise once a

week, structured exercise three times a week, or usual care (control group) by following age and baseline HbA1c. Community fitness centers served as the delivery site for the organized physical activity intervention. The once-weekly group participated in a single 60-minute session that included 30 minutes of resistance training with weights or resistance bands and 30 minutes of moderate-intensity aerobic activity, such as walking or cycling. Although they attended three meetings a week, the thrice-weekly group adhered to the same schedule. Without organized exercise sessions, the control group got normal T2D therapy from primary care physicians, which included general recommendations about a good diet and regular exercise. Participants were urged to continue their normal physical exercise outside of the program, and all sessions were overseen by certified fitness instructors to guarantee safety and proper technique. Changes in glycemic control, as determined by HbA1c and fasting blood glucose levels during a six-month period, were the main results. Changes in BMI, waist circumference, and metabolic indicators including triglycerides, HDL, LDL, and total cholesterol were other biomarkers. All measurements were taken by more professional way till six months of intervals through High performance liquid chromatography respectively. SPSS version 26.0 was used to analyze the raw data. Categorical variables were displayed as percentages and frequencies, whereas continuous variables were represented as (Mean \pm SD). Within-group comparisons were conducted using paired t-tests, whereas between-group comparisons were conducted using independent t-tests. To evaluate the interplay between time and group effects, a two-way ANOVA was conducted. P-values less than ($p \leq 0.05$) were regarded as statistically significant. The study was performed in accordance with the Declaration of Helsinki and authorized by Institutional Review Board (IRB) of Biological Sciences, Lahore-UBAS (a project of LM&DC). approval ref no. ERC/2024/09C before participant recruitment. All participants gave written informed consent, giving them voluntary participation and the confidentiality of their data. Participants were informed that they could withdraw from the study at any time without any harm whatsoever.

RESULTS

Table-1 shows Participants' baseline characteristics were split among the three groups: usual care (control), once-weekly exercise (G-B), and three-weekly exercise (G-A). G-A's median age was 60.1 years (IQR: 50.2–66.1), G-B's was 58.0 years (IQR: 50.1–64.0), and the control group's was 56.5 years (IQR: 49.0–63.8). Similar percentages of male and female participants were found in each group, with 40.1% of female participants in G-A and 39.0% in G-B and the control group, respectively. Graduate degrees were held by 42.0% of the control group, 30.3% of G-B, and 38.7% of G-A, indicating a small variation in educational achievement. Baseline clinical measurements

revealed variations across the groups. The control group had the highest median HbA1c at 7.4% (IQR: 6.9–8.2), followed by G-A at 7.1% (IQR: 6.7–8.0) and G-B at 7.2% (IQR: 6.8–8.1). Similar trends were seen in weight, with the control group weighing 94.0 kg (IQR: 85.0–110.0), G-A people weighing a median of 85.5 kg (IQR: 75.0–105.0), and G-B participants weighing 91.0 kg (IQR: 81.0–108.0). G-A had a slightly lower BMI (30.6 kg/m²; IQR: 28.5–34.9) than G-B (30.9 kg/m²; IQR: 28.0–36.5) and the control group (32.5 kg/m²; IQR: 28.8–37.0). G-A likewise had the smallest waist circumference, measuring 108.5 cm (IQR: 100.0–119.0), followed by G-B at 110.0 cm (IQR: 102.0–122.5) and the control group at 112.0 cm (IQR: 105.0–125.0). Fig-1 shows the thrice-weekly exercise group (G-A) showed the most significant reduction in HbA1c levels, demonstrating improved glycemic control. The once-weekly group (G-B) showed moderate improvement, while the control group exhibited minimal change.

Table-2 shows over a six-month period, the study looked at changes in glycemic control and physical activity levels in three groups: usual care (control), once-weekly exercise (G-B), and three-weekly exercise (G-A). With initial HbA1c readings of 7.68% for G-A, 7.64% for G-B, and 7.66% for the control group, the groups' levels were comparable. At three months, G-A's HbA1c levels dropped dramatically to 7.32%, G-B's to 7.36%, and the control

group's to 7.48%. G-A saw the biggest improvement after six months, with HbA1c falling to 7.10% from 7.38% in G-B. On the other hand, the control group showed the least improvement in glycemic control, with a modest rise to 7.54%. The MAQ score, which measures physical activity, showed a similar pattern. Scores at baseline were very similar, with the control group scoring 720, G-A scoring 740, and G-B scoring 730. After three months, the activity level of G-A participants increased significantly to 1150, while that of G-B participants climbed moderately to 830, and that of the control group increased marginally to 810. G-A scored 1110 at six months, which was little less than at three months, but it still maintained high activity levels. While the control group's activity decreased and fell below baseline to 660 points, G-B continued to improve to 950. These results demonstrate that the most successful strategy for increasing physical activity and glycemic control was three weeks of organized exercise. While the control group, which got standard care without organized physical activity, showed no improvement in glycemic control and a decrease in physical activity levels, the once-weekly exercise plan also revealed moderate advantages. Fig-2 shows physical activity levels, measured by MAQ scores, significantly increased in the thrice-weekly group (G-A), moderately improved in the once-weekly group (G-B), and declined in the control group.

Table- 1. Baseline parameters of Participant

Parameters	Thrice-weekly exercise (G-A)	Once-weekly exercise (G-B)	Usual care (control)
Age, median (IQR), y	60.1 (50.2-66.1)	58.0 (50.1-64.0)	56.5 (49.0-63.8)
Female, No. (%)	34 (40.1)	33 (39.0)	33 (39.0)
Male, No. (%)	34 (40.1)	33 (39.0)	33 (39.0)
Education			
Graduate Degree, No. (%)	46 (38.7)	36 (30.3)	50 (42.0)
Clinical Measures			
Hemoglobin A1c, %	7.1 (6.7-8.0)	7.2 (6.8-8.1)	7.4 (6.9-8.2)
Weight, kg	85.5 (75.0-105.0)	91.0 (81.0-108.0)	94.0 (85.0-110.0)
Body Mass Index (kg/m ²)	30.6 (28.5-34.9)	30.9 (28.0-36.5)	32.5 (28.8-37.0)
Waist Circumference, cm	108.5 (100.0-119.0)	110.0 (102.0-122.5)	112.0 (105.0-125.0)

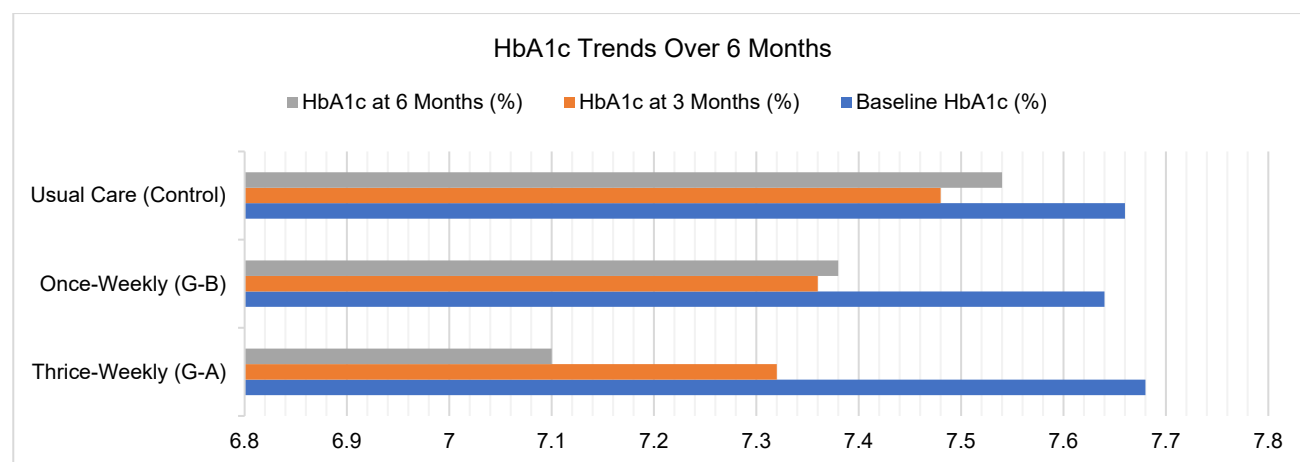
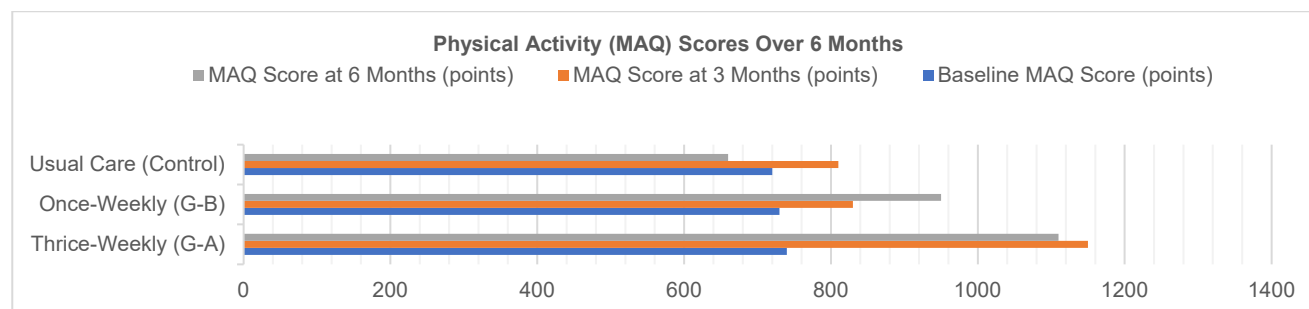


Figure-1: Changes in HbA1c levels over six months among three groups: thrice-weekly structured exercise (G-A), once-weekly structured exercise (G-B), and usual care (control). Thrice-weekly exercise showed the most significant reduction in HbA1c, indicating better glycemic control.

Table-2.: Baseline, 3-Month, and 6-Month Changes in Glycemic Control and Physical Activity

Parameters	Thrice-weekly exercise (G-A)	Once-weekly exercise (G-B)	Usual care (control)
Hemoglobin A1c Baseline (%)	7.68	7.64	7.66
Hemoglobin A1c at 3 months (%)	7.32	7.36	7.48
Hemoglobin A1c at 6 months (%)	7.10	7.38	7.54
MAQ Score Baseline (points)	740	730	720
MAQ Score at 3 months (points)	1150	830	810
MAQ Score at 6 months (points)	1110	950	660

**Figure-2:** Changes in Modifiable Activity Questionnaire (MAQ) scores over six months among three groups: The thrice-weekly structured exercise group (G-A) demonstrated the largest increase in physical activity levels, while the control group showed a decline.

The study found that the thrice-weekly exercise group (G-A) significantly improved their glycemic control and physical activity, with MAQ scores increasing from 740 to 1110 and HbA1c falling from 7.68% to 7.10% over the course of six months. With MAQ scores rising from 730 to 950 and HbA1c decreasing from 7.64% to 7.38%, the once-weekly group (G-B) demonstrated modest increases. On the other hand, the control group's MAQ scores decreased from 720 to 660 and their HbA1c increased somewhat from 7.66% to 7.54%. The most successful strategy for enhancing results was exercise three times a week.

DISCUSSION

Results of this study show that structured physical activity significantly improves glycemic control, metabolic and physical activity outcomes in patients with type 2 diabetes (T2D), particularly at a higher frequency of three sessions per week[9]. The results fit to previous research that exercise is the cornerstone in the management of T2D and it affects insulin sensitivity, glucose metabolism, and weight regulation. Nevertheless, the differences in outcomes between thrice weekly and once weekly exercise sessions highlight the role of exercise frequency in achieving optimal results[10, 11]. Clinically and statistically significant reduction of hemoglobin A1c (HbA1c) was observed in the thrice weekly group, and the average reduction after six months was 0.58%. The reduction is similar to, or greater, than what is achieved by pharmacological interventions for diabetes management. And the once weekly group also improved but the gains were more modest. Minimally, the usual care group (which did not engage in structured exercise) had minor changes

in HbA1c, emphasizing the important role of structured physical activity in improving glycemic status[12, 13].

The improvements in BMI and waist circumference were equally more marked in the thrice weekly group. The increased caloric expenditure and improved fat metabolism with increased exercise (i.e., more frequent exercise) likely contributed to substantial reduction in both BMI and waist circumference for this group. But in the once weekly group there were less dramatic changes, and the usual care group (which received no intervention) didn't improve these metabolic markers. What this means is that even moderate exercise is good, but only higher frequency will result in meaningful reductions in weight and abdominal fat[14]. The thrice weekly group also had significantly higher Modifiable Activity Questionnaire (MAQ) scores than the once weekly and usual care groups both at three and at six months. This is important as it has been shown that increased physical activity is associated with long term maintenance of glycemic control, improved cardiovascular health and lowered risk for diabetes complications. Structured programs to encourage patients to up their activity levels may be a sustainable way to manage T2D[15, 16]. However, this study has several limitations. The outcomes were variable, and the first might have been due to adherence to the exercise protocol, which was variable. If participants fully adhered to the prescribed exercise sessions, they probably experienced more benefit than those who didn't. In addition, the study followed up for only six months, so the long-term sustainability of these observed improvements is unknown [17]. Structured physical activity has future research opportunities to determine long term effects and strategies for improving adherence, especially for patients with poor exercise compliance[18]. Additionally, the study looked at structured aerobic and resistance training, but future

studies could extend the investigation into other styles of exercise, for example high intensity interval training (HIIT) or flexibility exercises, to see if those have similar effects on the glycemic control and metabolic health. The study also did not take into consideration dietary factors that could have played a role in the outcome. A more holistic approach to diabetes management may involve incorporating a lifestyle approach, including diet and behavior modification[19, 20].

CONCLUSION

Patients with type 2 diabetes benefit greatly from structured physical activity, especially three times a week, in terms of glucose management, physical activity levels, and metabolic outcomes (waist circumference and BMI). Compared to once-weekly exercise or standard treatment, this group showed greater improvements in metabolism and HbA1c reductions. These results emphasize how crucial regular exercise is for managing diabetes. For best results, future treatments should concentrate on improving adherence to exercise routines and take into account combining exercise with dietary or lifestyle changes.

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Author Contributions: All authors contributed equally to the conceptualization, design, execution, analysis, and writing of this study.

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Data Availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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