Original Article

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Effects of Periodized Circuit Training Versus Conventional Strength Training on Cardio metabolic and Pulmonary Outcomes in Type 2 Diabetes Mellitus: A Randomized Controlled Trial

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is associated with poor cardiovascular and metabolic outcomes. Although periodized circuit training (PCT) and conventional strength training (CST) are both recommended in the management of T2DM, the relative effectiveness of each training method across these multidimensional outcomes has not been clearly defined. Therefore, this study aimed to determine the effects of a 12-week PCT program with CST on pulmonary function, cardiovascular fitness, glycemic control, and Health related Quality of Life (HRQoL) in adults with T2DM.

Methods: Fifty adults with T2DM were randomly allocated to a PCT group (Group A, n=25) or a CST group (Group B, n=25) in a single-blind randomized controlled trial conducted at JPMC Hospital, Karachi. Both groups performed home-based training 3 times/week for 45-minute over 12 weeks. The baseline and post-intervention outcomes included FVC, FEV1, FEV1/FVC ratio, PEFR, six-minute walk test (6MWT) distance, HRQoL (SF-36), and HbA1c. Wilcoxon Signed-Rank and Mann–Whitney U were used for analysis.

Results: Both groups demonstrated important within-group improvement of most outcomes ($p < 0.05$). Between group analysis showed that there were no significant differences in FVC, FEV1, PEFR, 6MWT, HRQoL or HbA1c. Nevertheless, the FEV1/FVC ratio increased significantly in the PCT group compared to the CST group (83.52 ± 3.42% vs. 81.52 ± 2.85%; U=202.5, p=0.032), which is indicative of better airway efficiency.

Conclusion: Both PCT and CST are effective home-based interventions to improve pulmonary function, cardiovascular fitness, glycemic control and quality of life in T2DM patients. PCT demonstrated greater improvements in airway efficiency, suggesting broader pulmonary benefits.

Keywords: *Exercise Therapy, Glycated Hemoglobin A, Pulmonary Function Tests, Resistance Training, Type 2 Diabetes Mellitus*

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INTRODUCTION

Resistance of cell to take up insulin and relative deficiency of insulin are the hallmarks of type 2 diabetes (T2DM), a metabolic disease[1-2]. Long-term glucose elevation brought on by the illness has a significant risk of multiple system complications[3]. Seventy percent of patients with insulin independent diabetes died from cardiac and vascular disease, and new research indicates that pulmonary dysfunction, including forced expiratory volume (FEV1), forced vital capacity (FVC), and diffusion capacity, are additional clinically underappreciated consequences[4]. When compared to comparable non-diabetic populations, complications from diabetes are linked to lower quality of life related to health-as well as decreased physical and psychological well-being[5].

The American Diabetes Association, also known as the ADA, states that physical activity (APA) is the cornerstone of T2DM management[6]. People with insulin independent diabetes mellitus should also engage in resistance training twice to thrice a week to obtain at a minimum of 150 minutes moderate-intensity aerobic activity per week[7]. By increasing GLUT4 translocation in skeletal muscles, reducing visceral fat, and releasing myokines with anti-inflammatory qualities, exercise improves glycemic control[8]. In individuals with T2DM, structured exercise interventions have been demonstrated to lower glycated hemoglobin (HbA1c) levels by 0.6–0.7%, lower systolic blood pressure, and improve lipid levels[9]. We are unsure of the exercise modality that has the biggest overall impact on addressing the various cardiometabolic, pulmonary, and quality of life deficits associated with having T2DM, despite a strong collection of evidence[10].

Traditional ST (Strength Training) has been scientifically proven to have positive effects on overall muscular, bone mineral density, and insulin sensitivity, however, the lack of a strong cardiovascular component limits the effectiveness of the traditional ST system on cardiorespiratory fitness and pulmonary function[11]. Circuit training (CT) combines both Strengthen and aerobic training by performing both modalities sequentially at different stations[12]. When properly programmed with periodized variations in intensity, volume, and exercise selections, CT has the potential to provide multiple physiological adaptations while decreasing the chances of overtraining and plateaus of performance[13]. Therefore, when using the periodized CT (PCT) method, it may have the opportunity to provide more extensive physical benefits than either CST or CT alone with regard to the complex physiological issues associated with T2DM[14].

Despite the theory that PCT has multiple advantages over CST, there are limited studies that have conducted direct comparisons of these two ST methods on T2DM populations[15]. Most importantly, there is a lack of research on the differences between PCT and CST in reference to pulmonary outcomes, cardiorespiratory fitness, glycemic control, and HRQoL (Health Related Quality of Life) through the conduct of randomized controlled studies. This issue is of particular concern in limited resource clinical settings in which the prescription of exercise needs to be both efficient and effective. As a result, the objective of this randomized controlled trial is based on comparing the effects of periodized circuit training and conventional strength training on cardiovascular fitness, pulmonary function, level of glucose in blood, and health-related quality of life in adults having insulin independent diabetes mellitus in order to develop accessible, evidence-based exercise regimens for this group.

METHODOLOGY

Study Design and Setting

This randomized clinical trials with control groups were performed at JPMC Hospital, Karachi. The study was registered at ClinicalTrials.gov (Identifier: NCT07484672) and received ethical approval from Riphah International University (Protocol Record No. REC/RCR&AHS/24/0388). Data were collected from May 2025 to November 2025.

Sample Size

A sample size of n=42 participants was calculated using Epitool analysis software with 80% power and 95% confidence interval. Taking a value of 6-minute walk test at baseline (M0) 138±21 and after six months 137± 54 (M6)[16] from a reference study an aforementioned sample size was estimated. Following the addition of a 20% attrition rate, the final sample comprised 25 participants per group (total n = 50).

Selection Criteria

Participants of both genders aged group between 40 to 70 yrs, with a documented diagnosis of insulin independent diabetes mellitus with at least one year, HbA1c less than 10%, who were hemodynamically stable, insulin-independent, non-smokers, and without orthopedic limitations or gait and balance impairments were recruited. Individuals with uncontrolled blood pressure, severe cardiac disease, history of cardiac surgery, neurological or systemic comorbidities, pregnancy or lactation, or those engaged in any structured physical activity program within the preceding six months were excluded.

Data Collection Procedure

Data collection begins followed by ethical approval and ClinicalTrials.gov registration. Before enrollment in the Study model handwritten informed consent was received from all the subjects. Participants were screened priorly for eligibility and then using lottery method the two groups were randomly allocated. The study employed single-blind design, with the assessor physiotherapist blinded to group allocation. Baseline assessments included blood glucose monitoring, pulse oximetry, and sphygmomanometery.

Group A performed Periodized Circuit Training (PCT) comprising a session based on 45-minute, thrice a week, including a warm up session of 5-minute, aerobic exercise like (walking and jogging), session based on 20 minutes 15 minutes of resistance exercise (bodyweight and scissor exercises), and cool-down for 5-minute. Group B performed Conventional Strength Training (CST) comprising a sessions 45-minute, thrice a week, including a 5-minute warm-up, 35 minutes of strength and endurance training (of glute bridge, prone back extension, and ankle plantar flexion), and a 5-minute cool-down. Both interventions were home-based and conducted at moderate intensity.

Outcome Measures

All evaluation were conducted at baseline and after 3 months (approximately 12 weeks) of intervention.

i. **6-Minute Walk Test (6MWT)**
Cardiovascular fitness was assessed using the 6MWT, a submaximal exercise test measuring the maximum distance walked in six minutes along a flat 30-meter corridor[17]. Demonstrating excellent reliability and validity concerning functional capacity assessment, walk test in the window of 6-minute is also recommended by the American Thoracic Society guidelines for use in individuals with insulin independent diabetes mellitus (T2DM).

Spirometry assessment of pulmonary function was carried out using a calibrated digital spirometer adhering to the ATS/ERS standardized methods of measurement.

Forced Expiratory Volume in one second (FEV1), Forced Vital Capacity (FVC), FEV1/FVC ratio, and Peak Expiratory Flow Rate (PEFR) were recorded. Each participant performed a minimum of three acceptable maneuvers in a seated upright position, with the best effort recorded[18].

ii. **Health-Related Quality of Life (HRQoL)**
The assessment of Quality of life was obtained by using the SF-36 Health Survey, a validated 36-item self-reported questionnaire encompassing eight domains of physical and psychological well-being, each scored from 0 to 100, with higher scores reflecting better quality of life[19].

iii. **Glycemic Control**
HbA1c serves as the standardized marker for controlling blood glucose level for long period in T2DM management[20]. The values were taken at baseline and after twelve weeks of intervention to determine the effects of intervention on glycated hemoglobin levels.

Statistical Analysis

SPSS version 26 was use for data calculation and analysis. A level of significance was set at $p < 0.05$. The determination of data Normality was obtained by using a Kolmogorov-Smirnov test. Between group analyses was performed using a Mann-Whitney U test and within group analyses was performed using a Wilcoxon Signed-Rank Test. For representing demography of the recruited participants descriptive statistics was run and represented in the form of frequency and percentages.

Demographic Characteristics

A total of n=50 participants were enrolled and equally distributed between two groups (Group A with (Periodized Circuit Training, n = 25) and Group B with (Conventional Strength Training, n = 25). The overall mean age of participants was 54.66 ± 8.89 years, indicating that the sample predominantly comprised middle-aged to older adults. The mean BMI was 24.65 ± 4.90 kg/m² (table 1). Among the groups the participants, 32 (64%) were classified as overweight (BMI 25.0–29.9), 11 (22%) as obese (BMI ≥ 30.0), and 7 (14%) as having a healthy weight (BMI 18.5–24.9). There was equal gender distribution among the groups, with 25 males (50%) and 25 females (50%) across the total sample.

Table 1: Demographic Characteristics of Participants

Variable	N	Mean ± SD
Age (years)	50	54.66 ± 8.895
BMI (kg/m²)	50	24.65 ± 4.90
Frequency as per BMI Categories		

Category	Frequency	Percentage
Normal	7	14
Overweight	32	64
Obese	11	22
Frequency Gender wise distribution		
Male	25	50
Female	25	50

Normality Testing

The Shapiro-Wilk test confirmed that all baseline variables, including age, BMI, FEV1, FVC, FEV1/FVC, PEFR, HRQoL, HbA1c, 6MWT, heart rate, and SpO_2, were non-normally distributed (all $p < 0.05$). Accordingly, non-parametric statistical tests were applied for all subsequent analyses.

Effects of intervention after 12 weeks of treatment

Prior to treatment Mann-Whitney U test confirmed no statistical significance between-groups, the difference at baseline score across all outcome measures thus ensuring comparability of both groups.

In Group A there were statistically significant within-group improvement to nearly all outcomes associated with an intervention over 12 weeks. FEV1 improved from 2.32 ± 0.20 L to 2.59 ± 0.157 L (Z = −3.970, p < 0.001), the FEV1/FVC ratio increased from 79.56 ± 1.19 to 83.52 ± 3.42 (Z = −3.937, p < 0.001), and PEFR improved from 384.40 ± 21.80 to 402.80 ± 21.50 L/s (Z = −4.367, p < 0.001). FVC showed a non-significant increase from 2.96 ± 0.232 L to 3.09 ± 0.184 L (Z = −1.859, p = 0.063). Functional capacity measured by the 6MWT improved significantly from 539.20 ± 17.05 m to 593.20 ± 11.80 m (Z = −4.425, p < 0.001). HRQoL scores increased from 72.24 ± 1.62 to 79.20 ± 1.65 (Z = −4.415, p < 0.001), and HbA1c decreased significantly from 7.34 ± 0.14% to 6.70 ± 0.09% (Z = −4.397, p < 0.001).

Group B also had statistically significant improvements within group across all measures of functional ability). FVC improved from 2.87 ± 0.23 L to 3.13 ± 0.20 L (Z = −3.735, p < 0.001), FEV1 from 2.34 ± 0.185 L to 2.62 ± 0.14 L (Z = −3.786, p < 0.001), PEFR from 386.40 ± 19.97 to 406.80 ± 20.35 L/s (Z = −4.449, p < 0.001), and FEV1/FVC ratio from 79.56 ± 1.04 to 81.52 ± 2.85 (Z = 2.369, p = 0.018). The 6MWT distance improved from 541.20 ± 15.08 m to 596.40 ± 10.75 m (Z = 4.432, p < 0.001). HRQoL scores rose from 72.16 ± 1.40 to 78.84 ± 1.54 (Z = 4.412, p < 0.001), and HbA1c declined from 7.404 ± 0.124% to 6.74 ± 0.076% (Z = 4.396, p < 0.001). (Table 2)

Table 2: Effects of Intervention after 12 weeks of treatment

Outcome Measure	Group	Pre Mean ± SD	Post Mean ± SD	Z	p-value
FVC (L)	A	2.96 ± 0.232	3.09 ± 0.184	−1.859	0.063
	B	2.87 ± 0.23	3.13 ± 0.20	−3.735	<0.001
FEV1 (L)	A	2.32 ± 0.20	2.59 ± 0.157	−3.970	<0.001
	B	2.34 ± 0.185	2.62 ± 0.14	−3.786	<0.001
FEV1/FVC (%)	A	79.56 ± 1.19	83.52 ± 3.42	−3.937	<0.001
	B	79.56 ± 1.04	81.52 ± 2.85	2.369	0.018
PEFR (L/s)	A	384.40 ± 21.80	402.80 ± 21.50	−4.367	<0.001
	B	386.40 ± 19.97	406.80 ± 20.35	−4.449	<0.001
6MWT (m)	A	539.20 ± 17.05	593.20 ± 11.80	−4.425	<0.001
	B	541.20 ± 15.08	596.40 ± 10.75	4.432	<0.001
HRQoL	A	72.24 ± 1.62	79.20 ± 1.65	−4.415	<0.001
	B	72.16 ± 1.40	78.84 ± 1.54	4.412	<0.001
HbA1c (%)	A	7.34 ± 0.14	6.70 ± 0.09	−4.397	<0.001
	B	7.404 ± 0.124	6.74 ± 0.076	4.396	<0.001

Comparisons Between Two Intervention Approaches

There was no indication of significant difference when Mann-Whitney U test was performed in baseline scores for outcome measures between groups, confirming that both were representative of a similar population. After 12 weeks of treatment, post-treatment between group analysis indicated that all but one outcome was statistically similar between groups (i.e. FVC, FEV1, PEFR, 6MWT, HRQoL and HbA1c; all p-values >0.01) indicating both groups produced statistically similar improvements across the outcomes assessed. However, the FEV1/FVC ratio demonstrated a statistically significant difference between groups (U=202.5, p=0.032), with Group A demonstrating a more favorable improvement than Group B in their ability to perform pulmonary gas exchange.

Table 3: Between Group Analysis Mann-Whitney U Test (Post-Intervention)

Variable	Group A (PCT) Post Mean ± SD	Group B (CST) Post Mean ± SD	U-value	p-value
FVC (L)	3.09 ± 0.184	3.13 ± 0.20	274.5	0.442
FEV1 (L)	2.59 ± 0.157	2.62 ± 0.14	277.5	0.490
FEV1/FVC (%)	83.52 ± 3.42	81.52 ± 2.85	202.5	0.032*
PEFR (L/s)	402.8 ± 21.5	406.8 ± 20.35	262.5	0.316
6MWT (m)	593.20 ± 11.80	596.4 ± 10.75	262.5	0.316
HRQoL	79.20 ± 1.65	78.84 ± 1.54	262.5	0.316
HbA1c (%)	6.70 ± 0.09	6.74 ± 0.076	253.5	0.213

** Both periodized circuit training (PCT) and conventional strength training (CST) had statistically significant effects*

DISCUSSION

A randomized, controlled trial compared the effectiveness of 12 weeks of either periodized circuit training (PCT) or conventional strength training (CST) on not only pulmonary function but also cardiovascular fitness, glycemic control, and health-related quality of life for people with T2DM. As with all outcomes, both groups exhibited significant improvements within themselves as a group; however, the only significant difference (favoring PCT) between the two groups was with regard to the FEV1/FVC ratio.

For pulmonary function, both groups showed statistically significant improvements in FEV1, FEV1/FVC ratio, and PEFR; however, FVC did not show a statistically significant difference between groups A and B. The FEV1/FVC ratio improvements achieved by Group A (<0.032) as compared to Group B are consistent with another study that found positive effects from combined aerobic/ resistance training (A/R) on improving spirometric parameters for T2DM through increased respiratory muscle endurance and decreased systemic inflammation21. Walking and jogging during the aerobic portion of PCT likely assisted in the bronchodilation process and helped promote cardiorespiratory coupling, while increasing the strength of the diaphragm, therefore improving the efficiency of the airway beyond what was achieved by doing the CST alone[22]. These findings are contradicted by an alternate study that reported no difference in airway changes between A/R and R training and suggest that variations in the intervention methods or subjects, in combination with variations present within each of the samples used in those studies, may account for the differing results characteristics[23].

Both groups had equivalent, statistically significant improvements in distance (6MWT) regarding cardiovascular fitness with no statistically significant difference in distance covered between groups. This finding is consistent with other research showing resistance training results in improved functional walking capacity due to increased muscle-related energy production24. In both groups of participants, the aerobic elements of PCT replicated the demands of the 6-MWT protocol, while the resistance exercises produced strengthened/lowered limb muscle fatigue resulting in similar functional benefits over the short term. In addition to cardiovascular fitness, both groups experienced statistically significant reductions in HbA1c with no statistically significant group differences. This finding is also consistent with the body of literature on both resistance training and combined training as methods for increasing insulin sensitivity via GLUT4 translocation and AMPK activation25. Rhythmic large muscle aerobic exercises performed as part of the PCT protocol provided for acute, non-insulin-dependent glucose clearance while the resistance components in both groups allowed for similar muscle contractions resulting in increased post-exercise glucose uptake despite training at similar frequencies[26]. Similar improvements occurred in human quality of life measures for both groups with no statistically significant differences between groups. The improvement in quality of life as assessed by human quality of life measures is consistent with literature of evidence that exercise has a globally positive effect on human quality of life through improved physical and mental functioning[27-28]. Conclusion regarding the sustainability of the improvements observed is limited due to the home-based and balanced approach to the survey follow-up design.

The main strengths of this study are that it is a randomized controlled study that uses validated outcome measures in multiple physiological domains and home-based delivery model which increases its real-world applicability. But the results are to be interpreted with caution due to the short follow up of 12 weeks, lack of adherence monitoring and small size of the sample, and the lack of control over dietary and pharmacological confounders. Subsequent studies with longer intervention durations, larger multi-center samples with objective compliance monitoring, and include biomarkers, such as CRP and VO_2 peak, should be used in future studies to further explain the underlying physiological mechanisms of PCT in T2DM populations.

CONCLUSION

The study supports that both periodized circuit training and conventional strength training are effective interventions for improving pulmonary function, cardiovascular fitness, control of blood sugar levels and health-related quality of life in people with T2DM. However, periodized circuit training demonstrated a significantly superior improvement in airway efficiency, as reflected by the FEV1/FVC ratio, suggesting it may offer broader pulmonary benefits. Clinicians may consider PCT as a preferred home-based exercise modality for comprehensive T2DM management, though longer trials are warranted to confirm sustained outcomes.

Ethical Approval

The study was registered at ClinicalTrials.gov (Identifier: NCT07484672) and received ethical approval from Riphah International University (Protocol Record No. REC/RCR&AHS/24/0388). Data were collected from May 2025 to November 2025.

Author Contributions

HJ: Conception & Design, Data Collection, Manuscript Writing, and Critical Revision

HMG: Conception & Design, Data Analysis & Interpretation, and Final approval

SM: Data Collection and Final approval

MU: Data Analysis and Final approval

SKA: Conception & Design, Data Collection, and Critical Revision

Conflict of Interests

No conflict of interest.

Data Availability

Data will be available upon request.

Funding Source

No sources

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