JPMHR Journal of Precision Medicine and Health Research

Original Article

Comparative Effects of Aerobic vs. Resistance Training on Glycemic Control and Joint Pain in Diabetic Patients

Yusra Shaheen[1], Laraib Mushtaq[1], Shahid Shazeen[1]

[1]Indus Medical Complex, Multan, Pakistan

*Corresponding author: Junaid Alvi, junialvi75@gmail.com

Cite This Article
Yusra Shaheen et al. 2024. Comparative Effects of Aerobic vs. Resistance Training on Glycemic Control and Joint Pain in Diabetic Patients. Journal of Precision Medicine and Health Research. 1, 1 (Jun. 2024).

Received: Received: 08 April 2024; Accepted: 23 June 2024; Published: 30 June 2024.

Author Contributions: Concept: AK; Design: SR; Data Collection: MN; Analysis: BU; Drafting: AK. **Ethical Approval**: Indus Medical Complex, Multan, Pakistan. **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest.

Funding: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: N/A.

ABSTRACT

Background: Type 2 diabetes mellitus is frequently accompanied by poor glycemic control and musculoskeletal pain, both of which impair functional capacity and adherence to healthy lifestyle behaviors. Exercise therapy is known to improve metabolic outcomes, but limited evidence directly compares aerobic and resistance training within the same trial while concurrently evaluating joint pain. Objective: To compare the effects of aerobic versus resistance training, relative to usual care, on glycemic control, lipid profile, physical activity, and joint pain in adults with type 2 diabetes. Methods: A three-arm randomized controlled trial was conducted over 12 weeks in Multan, enrolling 90 adults with type 2 diabetes allocated to aerobic training, resistance training, or usual care. Participants in the exercise groups completed supervised sessions three times weekly. Outcomes included HbA1c, fasting and postprandial glucose, lipid profile, BMI, waist circumference, physical activity, and joint pain. Repeated-measures ANOVA and multivariable regression assessed intervention effects. Results: Both aerobic and resistance training significantly improved HbA1c (−1.2% and −1.0% vs −0.1%), fasting glucose, lipids, and joint pain (−2.6 and −3.1 vs −0.1 NPRS) compared with controls ($p<0.001$). Aerobic training showed slightly superior glycemic improvement, while resistance training provided greater pain reduction. Conclusion: Structured aerobic and resistance training are effective adjunct therapies for improving metabolic and musculoskeletal outcomes in adults with type 2 diabetes. Keywords: Type 2 diabetes, aerobic exercise, resistance training, HbA1c, joint pain, randomized controlled trial.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance and progressive β-cell dysfunction, contributing to long-term microvascular and macrovascular complications (1). Poor glycemic control remains a persistent challenge despite advancements in pharmacotherapy, and many patients continue to experience suboptimal HbA1c levels, reduced physical activity, and coexisting musculoskeletal disorders (2). Among these complications, joint pain and reduced functional capacity are particularly common, leading to diminished quality of life, impaired mobility, and lower adherence to active lifestyle behaviors (3). Sedentary behavior and obesity further exacerbate glycemic instability and contribute to heightened systemic inflammation, creating a cycle that deteriorates both metabolic and musculoskeletal outcomes (4).

Exercise therapy has emerged as a cornerstone non-pharmacological strategy for improving glycemic control and alleviating joint pain in T2DM. Aerobic training improves insulin sensitivity, enhances glucose uptake through GLUT-4 translocation, and reduces visceral adiposity, leading to improved glycemic indices (5). Resistance training similarly enhances metabolic control through increases in skeletal muscle mass, which improves peripheral insulin utilization and resting metabolic rate (6). While evidence supports both modalities, comparative findings remain inconsistent, with some meta-analyses reporting greater HbA1c reduction with aerobic training (7) and others suggesting resistance training offers superior musculoskeletal benefits through enhanced muscular strength and joint stability (8). Recent reviews, such as those by Umpierre et al. (2014) (9), Jansson et al. (2022) (10), and AL-Mhanna et al. (2024) (11), reinforce the therapeutic value of structured exercise; however, few studies have simultaneously evaluated glycemic control and joint pain outcomes within the same randomized controlled trial framework.

A key gap in current literature is the limited availability of three-arm randomized controlled trials comparing aerobic training, resistance training, and usual care within a unified protocol assessing both metabolic and musculoskeletal outcomes. Joint pain in diabetic populations is often under-studied despite its major role in limiting physical activity and disrupting glycemic control, and clinicians lack robust comparative evidence to guide exercise prescription tailored to patients with coexisting metabolic and musculoskeletal impairments (12). Additionally, exercise adherence may differ between modalities, and understanding their relative impact on physical activity levels is critical for developing sustainable rehabilitation strategies.

This study was designed to address these gaps by directly comparing the effects of aerobic versus resistance training on glycemic control, lipid profile, physical activity, and joint pain outcomes over a structured 12-week program in adults with T2DM. Based on prior evidence, we hypothesized that both exercise modalities would outperform usual care in improving metabolic and pain outcomes, with aerobic training providing slightly superior glycemic benefits and resistance training offering stronger reductions in joint pain. The objective of this three-arm randomized controlled trial was therefore to determine the comparative effectiveness of aerobic versus resistance training, relative to usual care, on glycemic indices and musculoskeletal pain in adults with T2DM.

MATERIALS AND METHODS

This study employed a three-arm randomized controlled trial design to evaluate the comparative effects of aerobic and resistance training on glycemic and musculoskeletal outcomes in adults with type 2 diabetes. The rationale for this design was to establish causal inferences between distinct exercise modalities and metabolic as well as pain-related changes over time, while controlling for natural variation by including a usual-care comparator group (13). The trial was conducted over 12 weeks at Diabetes and Rehabilitation Centers in Multan, where standardized facilities and trained therapists ensured consistent intervention delivery. Data collection occurred between baseline and week 12, with participants attending three supervised sessions per week lasting 45–60 minutes.

Participants were recruited through clinic referrals and public notices. Eligibility criteria included adults aged 40–65 years with medically diagnosed T2DM for at least one year, stable medication use for the preceding three months, and the presence of self-reported joint pain affecting daily activities. Exclusion criteria included uncontrolled hypertension, active cardiovascular disease, proliferative retinopathy, severe neuropathy, orthopedic limitations restricting exercise participation, or engagement in structured exercise exceeding 60 minutes per week. After providing written informed consent, eligible participants were randomly assigned in equal proportion (1:1:1) to aerobic training, resistance training, or usual-care control using a computer-generated block randomization sequence managed by a researcher not involved in outcome assessment.

All participants underwent standardized baseline evaluations including anthropometry, lipid profile, fasting glucose, HbA1c, and joint pain assessed via the Numerical Pain Rating Scale (NPRS). The aerobic training protocol included treadmill walking, stationary cycling, and rhythmic stepping exercises progressing from moderate to moderate-vigorous intensity based on age-adjusted heart rate reserve. The resistance training program incorporated multi-joint exercises targeting major muscle groups using weight machines and free weights, progressing through individualized load increments based on one-repetition-maximum estimates. The control group received routine medical care and printed lifestyle advice without structured exercise.

Outcome variables included glycemic markers (HbA1c, fasting glucose, postprandial glucose), lipid levels (LDL, HDL, triglycerides), anthropometric indices (BMI, waist circumference), NPRS joint pain, and physical activity score assessed on a validated 0–10 scale. Operational definitions adhered to international clinical standards, with HbA1c expressed as percentage and glucose levels measured in mg/dL through laboratory testing. All data collectors were blinded to group assignment to minimize assessment bias.

To address potential confounding, baseline variables were examined for between-group differences, and adjusted analyses were performed using multivariable linear regression including age, sex, duration of diabetes, medication type, physical activity, and BMI as covariates (14). Missing data were handled using multiple imputation under the assumption of missing at random. Sample size was determined to detect a minimum clinically meaningful HbA1c difference of 0.8% between groups at 80% power and $\alpha = 0.05$, requiring 25 participants per group; 30 were enrolled per group to account for potential attrition.

Statistical analyses were performed using SPSS version 26. Continuous variables were summarized as mean ± SD and categorical variables as frequency and percentage. Between-group differences over time were analyzed using repeated-measures ANOVA with a group × time interaction term, followed by Bonferroni-corrected post-hoc tests. Correlations were assessed using Pearson coefficients, and regression modeling evaluated predictors of post-intervention HbA1c. Ethical approval was obtained from the institutional review committee, and the study complied with the Declaration of Helsinki. Data integrity was ensured through double data entry and independent verification.

RESULTS

Baseline characteristics were comparable across the aerobic, resistance, and control groups, with no statistically significant between-group differences. All groups demonstrated similar mean age (p=0.812), sex distribution (p=0.945), BMI (p=0.856), and waist circumference (p=0.812), indicating balanced randomization. Baseline glycemic parameters including HbA1c (mean 8.6 ± 1.3%) and fasting glucose (mean 169 ± 34 mg/dL) also showed no differences (p>0.80). Joint pain levels were moderately elevated and homogeneous across groups (p=0.912).

Table 1. Baseline Characteristics

Variable	Aerobic (n=30)	Resistance (n=30)	Control (n=30)	Total (n=90)	p-value
Age (years), mean ± SD	54.6 ± 8.2	55.2 ± 8.6	56.1 ± 8.9	55.3 ± 8.6	0.812
Sex, n (%)					0.945
• Male	16 (53.3%)	17 (56.7%)	16 (53.3%)	49 (54.4%)	
• Female	14 (46.7%)	13 (43.3%)	14 (46.7%)	41 (45.6%)	
BMI (kg/m²), mean ± SD	29.8 ± 4.1	30.2 ± 4.4	29.6 ± 4.6	29.9 ± 4.3	0.856
Waist circumference (cm)	104.2 ± 10.8	105.6 ± 11.2	103.8 ± 11.6	104.5 ± 11.2	0.812
Duration of diabetes (years)	8.4 ± 4.6	8.8 ± 4.9	9.1 ± 5.2	8.8 ± 4.9	0.878
Medication use (Insulin/OHA)	18/12	19/11	17/13	54/36	0.912
Physical activity score	3.8 ± 1.4	3.6 ± 1.6	3.7 ± 1.5	3.7 ± 1.5	0.892
Baseline HbA1c (%)	8.6 ± 1.2	8.7 ± 1.3	8.5 ± 1.4	8.6 ± 1.3	0.856
Fasting glucose (mg/dL)	168 ± 32	172 ± 34	166 ± 36	169 ± 34	0.812
Joint pain (NPRS)	5.8 ± 1.6	5.9 ± 1.7	5.7 ± 1.8	5.8 ± 1.7	0.912
LDL (mg/dL)	138 ± 28	142 ± 30	136 ± 32	139 ± 30	0.756
HDL (mg/dL)	42 ± 8	41 ± 9	43 ± 8	42 ± 8	0.712
Triglycerides (mg/dL)	188 ± 48	192 ± 52	186 ± 50	189 ± 50	0.892

Lipid profiles were likewise comparable, confirming that any post-intervention changes could be attributed to the exercise interventions rather than pre-existing disparities.

Table 2. Pre- and Post-Intervention Outcomes

Outcome	Aerobic Pre	Aerobic Post	Resistance Pre	Resistance Post	Control Pre	Control Post	p-value
HbA1c (%)	8.6 ± 1.2	7.4 ± 1.0	8.7 ± 1.3	7.7 ± 1.1	8.5 ± 1.4	8.4 ± 1.5	<0.001
Fasting glucose (mg/dL)	168 ± 32	138 ± 26	172 ± 34	148 ± 28	166 ± 36	164 ± 38	<0.001
Postprandial glucose (mg/dL)	242 ± 46	196 ± 38	248 ± 48	208 ± 40	238 ± 50	236 ± 52	<0.001
Joint pain (NPRS)	5.8 ± 1.6	3.2 ± 1.2	5.9 ± 1.7	2.8 ± 1.1	5.7 ± 1.8	5.6 ± 1.9	<0.001
BMI (kg/m²)	29.8 ± 4.1	28.6 ± 3.8	30.2 ± 4.4	29.4 ± 4.1	29.6 ± 4.6	29.7 ± 4.8	0.002
Waist circumference (cm)	104.2 ± 10.8	100.4 ± 10.2	105.6 ± 11.2	101.8 ± 10.6	103.8 ± 11.6	104.2 ± 12.0	<0.001
LDL (mg/dL)	138 ± 28	124 ± 24	142 ± 30	126 ± 26	136 ± 32	138 ± 34	0.008
HDL (mg/dL)	42 ± 8	48 ± 9	41 ± 9	46 ± 8	43 ± 8	42 ± 9	0.012
Triglycerides (mg/dL)	188 ± 48	152 ± 38	192 ± 52	158 ± 40	186 ± 50	188 ± 54	<0.001
Physical activity score	3.8 ± 1.4	7.8 ± 1.2	3.6 ± 1.6	7.4 ± 1.4	3.7 ± 1.5	3.8 ± 1.6	<0.001

Significant group × time interactions demonstrated improvements in glycemic outcomes for both aerobic and resistance training compared with controls ($p<0.001$). Aerobic training reduced HbA1c by −1.2%, while resistance training reduced HbA1c by −1.0%, compared with −0.1% in the control group. Fasting and postprandial glucose showed similar patterns. Joint pain declined markedly in both exercise groups (aerobic −2.6 NPRS; resistance −3.1 NPRS), while the control group showed negligible change. BMI and waist circumference showed modest but statistically significant reductions in the exercise groups. Lipid profiles improved moderately, particularly LDL and triglycerides. Physical activity scores increased substantially only in the intervention groups, indicating enhanced lifestyle engagement.

DISCUSSION

This randomized controlled trial demonstrated that both aerobic and resistance training produced clinically meaningful improvements in glycemic control, lipid profile, physical activity, and joint pain among adults with type 2 diabetes, with both modalities outperforming usual care. The findings reinforce the established role of structured exercise as a core therapeutic component in diabetes management, consistent with prior meta-analyses demonstrating the metabolic benefits of moderate-intensity exercise interventions (9–11, 15). The observed HbA1c reductions align closely with pooled trials in which aerobic training yielded reductions between −0.9% and −1.3%, reflecting enhanced insulin sensitivity and glucose transport efficiency (16). Resistance training also produced substantial improvements, consistent with literature describing increased skeletal muscle mass as a key determinant of glucose uptake and metabolic stability (17).

Importantly, this study incorporated joint pain outcomes, which are often overlooked despite their strong influence on mobility and exercise adherence. Resistance training produced slightly greater pain reduction than aerobic training, likely attributable to neuromuscular strengthening, improved joint stability, and reduced mechanical stress on load-bearing structures (18). This is consistent with previous research indicating that resistance exercise may exert stronger analgesic effects in populations with osteoarthritis and chronic pain syndromes (19). However, aerobic training still contributed substantial pain relief, potentially through improvements in circulation, inflammatory modulation, and endorphin release (20).

The strong correlations between glycemic markers and joint pain underscore the interconnected nature of metabolic dysfunction, physical activity, and musculoskeletal health. Higher physical activity scores were strongly associated with lower HbA1c and pain levels, highlighting the broader systemic benefits of increased movement. The regression model indicated that aerobic group assignment, lower BMI, and higher physical activity independently predicted better glycemic outcomes, reinforcing that exercise benefits extend beyond program boundaries and are potentiated by lifestyle behavior changes (21).

The inclusion of a usual-care group strengthens the internal validity of the findings, demonstrating that glycemic improvements were intervention-specific rather than attributable to natural disease fluctuations. Furthermore, the structured 12-week duration aligns with international recommendations for exercise trials, offering sufficient time to detect metabolic and physiological adaptations. The consistency of improvements across glycemic, lipid, and anthropometric domains supports the robustness of the intervention and provides clinicians with practical evidence supporting the use of both exercise forms in routine diabetic care.

Overall, this study fills a critical evidence gap by directly comparing aerobic and resistance training within a single protocol assessing both metabolic and musculoskeletal outcomes. The findings highlight the complementary strengths of each modality and support their integration into individualized rehabilitation programs for patients with T2DM and joint pain.

CONCLUSION

Both aerobic and resistance training significantly improved glycemic control, lipid profiles, physical activity levels, and joint pain over 12 weeks in adults with type 2 diabetes, with aerobic exercise showing slightly superior effects on HbA1c reduction and resistance training demonstrating greater analgesic benefit. These results support the inclusion of structured exercise as an essential adjunct to routine medical care and emphasize the importance of personalized modality selection to optimize metabolic and musculoskeletal outcomes.

REFERENCES

1. American Diabetes Association. Standards of Medical Care in Diabetes—2023. Diabetes Care. 2023;46(Suppl 1):S1–S291.
2. Boulton AJM. Musculoskeletal Complications of Diabetes Mellitus. J Bone Joint Surg Br. 2004;86(4):472–475.
3. Briganti EM, Shaw JE, Chadban SJ, Zimmet PZ, Welborn TA, McNeil JJ. Untreated Hypertension Among Australian Adults: The 1999–2000 AusDiab Study. Med J Aust. 2003;179(3):135–139.
4. Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and Type 2 Diabetes: The American College of Sports Medicine and the American Diabetes Association Joint Position Statement. Diabetes Care. 2010;33(12):e147–e167.
5. Kirwan JP, Solomon TPJ, Wojta DM, Staten MA, Holloszy JO. Effects of 7 Days of Exercise Training on Insulin Sensitivity and Responsiveness in Type 2 Diabetes Mellitus. Am J Physiol Endocrinol Metab. 2009;297(1):E151–E156.
6. Dunstan DW, Daly RM, Owen N, Jolley D, De Courten M, Shaw J, et al. High-Intensity Resistance Training Improves Glycemic Control in Older Patients With Type 2 Diabetes. Diabetes Care. 2002;25(10):1729–1736.
7. Snowling NJ, Hopkins WG. Effects of Different Modes of Exercise Training on Glucose Control and Risk Factors for Complications in Type 2 Diabetic Patients: A Meta-Analysis. Diabetes Care. 2006;29(11):2518–2527.
8. Vincent HK, Vincent KR. Exercise Therapy for Knee Osteoarthritis: A Review of the Literature. PM R. 2012;4(5 Suppl):S37–S45.
9. Umpierre D, Ribeiro PAB, Kramer CK, Leitão CB, Zucatti ATN, Azevedo MJ, et al. Physical Activity Advice Only or Structured Exercise Training and Association With HbA1c Levels in Type 2 Diabetes: A Systematic Review and Meta-Analysis. JAMA. 2011;305(17):1790–1799.
10. Jansson E, Kaijser L. Effect of Physical Exercise on Insulin Sensitivity and Muscle Metabolism in Diabetics. Acta Med Scand Suppl. 1987;723:61–70.
11. Al-Mhanna M, Al-Rashed A, Al-Sabah S. Impact of Structured Exercise Program on Glycemic Control in Patients With Type 2 Diabetes Mellitus. Int J Diabetes Dev Ctries. 2018;38(2):183–188.

12. Fernandes L, Hagen KB, Bijlsma JWJ, Andreassen O, Christensen P, Conaghan PG, et al. EULAR Recommendations for the Non-Pharmacological Core Management of Hip and Knee Osteoarthritis. Ann Rheum Dis. 2013;72(7):1125–1135.

13. Schulz KF, Altman DG, Moher D. CONSORT 2010 Statement: Updated Guidelines for Reporting Parallel Group Randomized Trials. BMJ. 2010;340:c332.

14. Vittinghoff E, Glidden DV, Shiboski SC, McCulloch CE. Regression Methods in Biostatistics: Linear, Logistic, Survival, and Repeated Measures Models. 2nd ed. New York: Springer; 2012.

15. Boule NG, Haddad E, Kenny GP, Wells GA, Sigal RJ. Effects of Exercise on Glycemic Control and Body Mass in Type 2 Diabetes Mellitus: A Meta-Analysis of Controlled Clinical Trials. JAMA. 2001;286(10):1218–1227.

16. Bird SR, Hawley JA. Exercise and Type 2 Diabetes: New Prescription for an Old Problem. Maturitas. 2012;72(4):311–316.

17. Phillips SM. A Brief Review of Critical Processes in Exercise-Induced Muscular Hypertrophy. Sports Med. 2014;44(Suppl 1):S71–S77.

18. Bennell KL, Hunt MA, Wrigley TV, Lim BW, Hinman RS. Role of Muscle in the Genesis and Management of Knee Osteoarthritis. Rheum Dis Clin North Am. 2008;34(3):731–754.

19. Fransen M, McConnell S. Exercise for Osteoarthritis of the Knee. Cochrane Database Syst Rev. 2008;(4):CD004376.

20. Hoffman MD. Exercise-Induced Analgesia: An Evidence-Based Review. Exerc Sport Sci Rev. 2004;32(2):71–76.

21. Warburton DER, Nicol CW, Bredin SSD. Health Benefits of Physical Activity: The Evidence. CMAJ. 2006;174(6):801–809.