

Research Article

The Effect of Moderate-Intensity Aerobic Exercise on Fasting Blood Sugar (FBS) and Hemoglobin A1c (HbA1c) Levels in Women with Type 2 Diabetes

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Abstract

Introduction: Type 2 diabetes is one of the most common chronic metabolic diseases, characterized by impaired glucose metabolism. This study aimed to investigate the effect of moderate-intensity aerobic exercise on fasting blood sugar (FBS) and hemoglobin A1c (HbA1c) levels in women with type 2 diabetes..

Methods: This quasi-experimental study employed a pretest-posttest control group design. Thirty women with type 2 diabetes, aged 40 to 50 years, were purposefully selected from the Diabetes Center of Yazd Province and randomly assigned to either the training group (n = 15) or the control group (n = 15). The training group performed moderate-intensity aerobic exercises for 8 weeks. Data were analyzed using paired and independent t-tests at a significance level of 0.05.

Results: The findings showed that after the exercise intervention, the training group experienced a significant reduction in FBS and HbA1c levels (p < 0.001), whereas no significant change was observed in the control group (p > 0.05). Moreover, the independent t-test confirmed significant differences between the two groups in the reduction of both indices.

Conclusion: Moderate-intensity aerobic exercise, as a non-pharmacological intervention, can play a significant role in improving FBS and HbA1c levels in women with type 2 diabetes and should be considered in the treatment programs for these patients.

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1. Introduction

Type 2 diabetes is one of the most prevalent and costly chronic diseases worldwide, and due to its rapidly increasing prevalence and numerous complications, it has become a major global public health crisis (1). This metabolic disorder results from impaired insulin secretion and insulin resistance, leading to chronic hyperglycemia, which can eventually cause dysfunction in various organ systems, including the heart, kidneys, eyes, and nervous system (2). According to reports from the World Health Organization (WHO) and the International Diabetes Federation (IDF), more than 460 million people worldwide are currently living with diabetes, of whom approximately 90–95% have type 2 diabetes (3). It is estimated that this number will rise to over 700 million by 2045 (4). In Iran as well, the prevalence of this disease has been significantly increasing over recent decades, particularly among middle-aged women, which is cause for concern (5).

Middle-aged women are at higher risk for developing type 2 diabetes and its complications due to various factors, including hormonal changes during menopause, decreased physical activity, weight gain, and central obesity (6). This group requires special attention and targeted therapeutic and preventive interventions to slow the progression of the disease, reduce complications, and preserve their quality of life (6).

Among the most important indicators for evaluating diabetes control are fasting blood sugar (FBS) and hemoglobin A1c (HbA1c) levels (8). While FBS reflects short-term glucose levels (9),

HbA1c indicates the average blood glucose over the past two to three months and serves as a key marker for predicting diabetic complications and assessing treatment success (10). Even a one percent reduction in HbA1c is associated with a significant decrease in the risk of microvascular and macrovascular complications (11).

Management of type 2 diabetes includes both pharmacological and non-pharmacological interventions, with lifestyle modification—especially physical activity—being a cornerstone of treatment (12). Exercise, particularly aerobic activity, has been shown to improve insulin sensitivity, glucose uptake by muscles, body composition, and cardiovascular function (13). Several studies have demonstrated that regular aerobic activity can significantly reduce FBS and HbA1c levels and improve metabolic control in diabetic patients (14–17).

However, the effectiveness of aerobic exercise depends on factors such as intensity, duration, and exercise pattern, which must be tailored to the specific characteristics of different patient groups. Numerous studies have reported varying results. For example, Gholami et al. (2017) investigated the effects of eight weeks of low- and moderate-intensity aerobic training on HbA1c, hematological factors, and body fat percentage in overweight and obese men with type 2 diabetes. They found significant reductions in HbA1c, glucose, and body fat in both training groups ($p < 0.05$), while lipid profile improvements were significant only in the moderate-intensity group. Additionally, reductions in HbA1c and increases in VO_{2peak} were significantly greater in the moderate-intensity group compared to the low-intensity group (18).

Samadpour et al. (2022) examined the effects of eight weeks of TRX resistance training combined with taurine supplementation on glycemic indices in women with type 2 diabetes. They found significant reductions in HbA1c in the supplement ($p = 0.027$), training ($p = 0.001$), and combined supplement + training groups ($p = 0.001$), with no significant changes in the control group ($p > 0.05$). The FBS level in the training group was statistically lower than in the supplement + training group ($p = 0.012$) (19).

Kalantari et al. (2021) studied the effects of aerobic exercise and soy isoflavone supplementation (Glycine soja) on changes in HbA1c and FBS in patients with type 2 diabetes. All four groups showed significant reductions in FBS and HbA1c in both women and men ($p < 0.05$). However, between-group comparisons revealed significant differences only in FBS levels among men ($p < 0.05$), with no significant differences in HbA1c (20).

Chouk et al. (2025) investigated the effects of a combined dietary and physical activity program on blood glucose control and body composition in recreational male athletes with type 2 diabetes. Their findings suggested that a therapeutic diet combined with physical activity effectively improved body composition and biochemical parameters, offering a comprehensive strategy for managing diabetes in physically active individuals (21).

Shah et al. (2021) explored the impact of short-term moderate-intensity physical activity on blood glucose control and antioxidant status in a prediabetic population. They observed a significant increase in individual antioxidants, nominal improvement in total antioxidant capacity, and decreased uric acid levels after eight weeks of moderate physical activity, along with notable reductions in anthropometric and glycemic profiles (22).

Ambelu et al. (2023) assessed the effects of exercise on blood glucose, blood pressure, and body composition in patients with type 2 diabetes. Their findings indicated that the combined intervention (aerobic plus resistance training) led to significantly greater improvements in body composition, blood pressure, and FBS compared to either intervention alone, suggesting the superior effectiveness of combined training protocols (23).

These findings highlight the need for targeted research on specific high-risk populations, such as middle-aged women, who face greater challenges due to hormonal changes, reduced muscle mass, and sedentary lifestyles. This population may benefit from tailored and feasible exercise programs whose effects on metabolic markers of diabetes should be carefully evaluated.

Accordingly, the present study was conducted to investigate the effect of moderate-intensity aerobic exercise on fasting blood sugar and HbA1c levels in women with type 2 diabetes. The findings may offer practical and scientific insights for non-pharmacological management of type 2 diabetes and serve as a reference for designing customized exercise interventions. Furthermore, this research could contribute to improving quality of life and reducing diabetes-related complications among middle-aged women, while advancing scientific knowledge in the field of chronic disease management.

2. Materials and Methods

This study was conducted as an experimental pretest-posttest design with a control group. A total of 30 women with type 2 diabetes, aged between 40 and 50 years and with at least three years of membership at the Diabetes Center of Yazd Province, were selected through purposive and convenient sampling. Considering the limited target population and consistency with previous studies, this sample size was deemed sufficient to detect the effects of moderate-intensity aerobic exercise. After confirming eligibility, participants were randomly assigned to either the control group (n = 15) or the training group (n = 15), in order to assess the impact of exercise on quality of life.

Inclusion criteria were: age between 40 and 50 years, diagnosis of type 2 diabetes for at least three years, fasting blood sugar (FBS) level greater than 126 mg/dL, use of similar medications for glycemic control, adherence to the dietary guidelines recommended by the diabetes center, non-smoking status, no history of cardiovascular, hepatic, or infectious diseases affecting inflammatory markers, and no engagement in regular or intense exercise during the past three months.

Exclusion criteria included: unwillingness to continue participation, non-compliance with the exercise program or intervention protocol, occurrence of serious or hazardous complications, unwanted changes in medications or treatment regimen, development of new medical conditions, or any physical or psychological conditions unsuitable for continued participation, as well as absence from sessions or sampling. All participants voluntarily participated in the study after being informed of its details and signing a written informed consent form. All ethical considerations were fully observed.

Fasting blood sugar was measured using a glucometer, and HbA1c levels were assessed using either the HPLC method or immunoassay.

One week before the beginning of the intervention, participants attended an orientation session, during which safety instructions related to treadmill use and proper running technique were explained.

The aerobic exercise program consisted of a progressive treadmill running protocol with varying intensities:

Weeks 1–2: 35–45% of maximum heart rate (HRmax)

Weeks 3–4: 45–55% HRmax

Weeks 5–6: 55–65% HRmax

Weeks 7–8: 65–75% HRmax

Each session lasted 50 minutes and included a 10-minute warm-up, 30 minutes of continuous main aerobic activity, and a 10-minute cool-down. The exercise was performed three times per week. The detailed training protocol is summarized in Table 1 (24).

Table 1. Aerobic Training Program Details

Week	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Intensity (% HRmax)	35-45	35-45	45-55	45-55	55-65	55-65	65-75	65-75
Session Duration (min)	40-50	40-50	40-50	40-50	40-50	40-50	40-50	40-50
Sessions per Week	3	3	3	3	3	3	3	3

Data were analyzed using SPSS version 26. The normality of the data was assessed using the Kolmogorov-Smirnov test. Paired and independent t-tests were used to compare the group means. The significance level for all statistical tests was set at 0.05.

3. Results

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Table 2 presents the means and standard deviations of the study variables for the training and control groups at both pretest and posttest stages.

Variable	Group	Stage	N	Minimum	Maximum	Mean	Standard Deviation
FBS	Training	Pretest	15	135.97	178.37	156.34	14.24
	Training	Posttest	15	92.79	147.06	123.97	14.62
	Control	Pretest	15	126.27	163.73	147.55	12.63
	Control	Posttest	15	122.33	163.57	146.53	14.11
HbA1c	Training	Pretest	15	7.11	9.75	8.57	0.72
	Training	Posttest	15	6.18	8.90	7.42	0.80
	Control	Pretest	15	7.06	10.00	8.42	0.92
	Control	Posttest	15	6.98	10.09	8.46	0.92

Table 3 presents the changes in fasting blood sugar (FBS) in patients with type 2 diabetes following moderate-intensity aerobic exercise. A paired t-test was conducted to compare the mean differences in FBS before and after the intervention within both the experimental (training) and control groups.

Table 3. Paired t-test Results Comparing Changes in Fasting Blood Sugar (FBS) in Training and Control Groups

Group	Paired Differences	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	p (two-tailed)
Training	Post-FBS – Pre-FBS	-32.37	8.63	2.23	-37.15 to -27.59	-14.52	14	0.000
Control	Post-FBS – Pre-FBS	-1.02	3.05	0.78	-2.71 to 0.66	-1.30	14	0.214

Training Group: In the training group, the mean difference in FBS levels before and after the aerobic exercise intervention was -32.37, indicating a significant reduction in FBS following the exercise program. The standard deviation of this difference was 8.63, and the standard error of the mean was 2.23. The 95% confidence interval for the mean difference ranged from -37.15 to -27.59, which does not include zero, further confirming the significant decrease in FBS. The t-value was -14.52 with a p-value of 0.000, indicating that the change was statistically significant.

Control Group: In the control group, the mean difference in FBS was -1.02, suggesting a slight decrease in FBS levels; however, this change was not statistically significant. The standard deviation was 3.05, and the standard error of the mean was 0.78. The 95% confidence interval ranged from -2.71 to 0.66, including zero, which indicates no significant difference in FBS levels. The t-value was -1.30 and the p-value was 0.214, demonstrating that the observed changes in the control group were not statistically significant and likely due to chance.

Table 4 presents the results of an independent t-test used to examine significant differences between the training and control groups regarding changes in fasting blood sugar (FBS). The detailed outcomes of this test are provided in the following table.

Table 4. Independent t-test Results Comparing Changes in Fasting Blood Sugar (FBS) Between Training and Control Groups

Test Assumption	F	Sig.	t	df	p (two-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
Equal variances assumed	3.687	0.065	19.311	28	0.000	5.4953	0.2846	4.9124 to 6.0782
Equal variances not assumed			19.311	23.005	0.000	5.4953	0.2846	4.9067 to 6.0839

The Levene’s test for equality of variances showed a significance value (Sig.) of 0.065, which is greater than 0.05. Therefore, the null hypothesis of equal variances is accepted, and the analysis proceeded using the “Equal variances assumed” row.

The results of the independent t-test indicated a t-value of 19.311 and a significance level (Sig.) of 0.000, which is less than 0.05. Hence, there is a statistically significant difference between the training and control groups in terms of fasting blood sugar (FBS) levels. These findings demonstrate that the changes in FBS differ significantly between the two groups.

The mean difference between groups was 5.4953, indicating a significant increase in FBS level in one group compared to the other. The 95% confidence interval for the mean difference ranged from 4.9124 to 6.0782 under the assumption of equal variances. These values confirm a significant positive difference in fasting blood sugar levels between the training and control groups.

Table 5 presents the changes in hemoglobin A1c (HbA1c) in patients with type 2 diabetes following moderate-intensity aerobic exercise. A paired t-test was employed to compare the mean differences in HbA1c before and after the intervention within both the experimental (training) and control groups.

Table 5. Paired t-test Results Comparing Changes in Hemoglobin A1c (HbA1c) in Training and Control Groups

Group	Paired Differences	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	p (two-tailed)
Training	Post-HbA1c – Pre-HbA1c	-1.15	0.28	0.07	-1.30 to -0.99	-16.13	14	0.000
Control	Post-HbA1c – Pre-HbA1c	0.04	0.12	0.03	-0.02 to 0.10	1.32	14	0.206

Training Group: In the training group, the mean difference in HbA1c levels before and after the aerobic exercise intervention was -1.15, indicating a significant reduction in HbA1c following the exercise program. The standard deviation of this difference was 0.28, and the standard error of the mean was 0.07. The 95% confidence interval for the mean difference ranged from -1.30 to -0.99, which does not include zero, further confirming the significant decrease in HbA1c. The t-value was -16.13 with a p-value of 0.000, indicating that the change was statistically significant.

Control Group: In the control group, the mean difference in HbA1c was 0.04, suggesting a negligible change in HbA1c levels; however, this change was not statistically significant. The standard deviation was 0.12, and the standard error of the mean was 0.03. The 95% confidence interval ranged from -0.02 to 0.10, including zero, indicating no significant difference in HbA1c levels. The t-value was 1.32 and the p-value was 0.206, demonstrating that the observed changes in the control group were not statistically significant and likely due to chance. Table 6 presents the results of an independent t-test used to examine significant differences between the training and control groups regarding changes in hemoglobin A1c (HbA1c). The detailed outcomes of this test are provided in the following table.

Table 6. Independent t-test Results Comparing Changes in Hemoglobin A1c (HbA1c) Between Training and Control Groups

Test Assumption	F	Sig.	t	df	p (two-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
Equal variances assumed	20.027	0.000	-15.375	28	0.000	-1.1913	0.0775	-1.3500 to -1.0326
Equal variances not assumed			-15.375	18.850	0.000	-1.1913	0.0775	-1.3536 to -1.0291

Levene's test for equality of variances indicated a significance value (Sig.) of 0.000, which is less than 0.05. Therefore, the null hypothesis of equal variances was rejected, and the analysis was conducted using the "Equal variances not assumed" row.

The results of the independent t-test showed a t-value of -15.375 and a significance level (Sig.) of 0.000, which is less than 0.05. Thus, there is a statistically significant difference between the training and control groups in HbA1c levels. These findings indicate that the changes in HbA1c differ significantly between the two groups.

The mean difference between groups was -1.1913, indicating a significant reduction in HbA1c levels in the training group compared to the control group. The 95% confidence interval for the mean difference ranged from -1.3536 to -1.0291 under the assumption of unequal variances. These values represent a significant negative difference in HbA1c levels between the groups.

4. Discussion

The results of the present study clearly demonstrated that moderate-intensity aerobic exercise has a significant effect on reducing fasting blood sugar (FBS) and glycated hemoglobin (HbA1c) levels in women with type 2 diabetes. Considering that both of these markers play a key role in controlling and evaluating the metabolic status of diabetic patients, these findings are particularly important. The significant reduction in FBS and HbA1c in the exercise group compared to the control group, which showed no significant changes, clearly confirms the positive impact of the exercise intervention.

In the exercise group, a 32.37-unit decrease in FBS after a period of moderate-intensity aerobic exercise reflects a significant improvement in insulin response, increased insulin sensitivity, and reduced cellular insulin resistance

Aerobic exercise contributes to blood glucose regulation through mechanisms such as increased glucose uptake by active muscles, increased number and sensitivity of insulin receptors on muscle cell membranes, and stimulation of insulin-independent glucose uptake. Furthermore, aerobic exercise activates enzymes involved in glucose and fatty acid oxidation pathways, ultimately enhancing glucose control.

Another important finding of this study was the significant reduction in HbA1c levels. HbA1c, reflecting the average blood glucose level over the past two to three months, is a primary indicator in assessing long-term diabetes control. The 1.15% reduction in HbA1c in the exercise group suggests that the effect of aerobic exercise is not only short-term and transient but also sustainably effective in glucose regulation.

These findings are consistent with those of Gholami et al. (2017), Samadpour et al. (2022), Kalantari et al. (2021), Chouk et al. (2025), Shah et al. (2021), and Ambelu et al. (2023) (18, 19, 20, 21, 22, 23). This alignment between the present study and previous research strengthens the validity and generalizability of the results.

Physiologically, aerobic exercise enhances capillary volume, increases oxygen delivery to tissues, raises mitochondrial density in muscle cells, and improves fat oxidation capacity, all of which contribute to improved glucose metabolism and better blood glucose control. Moreover, aerobic exercise reduces visceral fat and systemic inflammation, both of which play direct roles in insulin resistance. Therefore, the reduction in HbA1c observed in this study can be attributed to a cascade of these positive metabolic adaptations.

In contrast, the control group did not exhibit any significant changes in FBS or HbA1c levels. This clearly highlights the specific effect of the exercise intervention and indicates that mere passage of time or unrelated environmental factors cannot significantly improve these markers. This finding is especially important for therapeutic planning and prevention of diabetes complications,

as it demonstrates that without effective intervention, the metabolic status of diabetic patients remains unchanged or may even worsen (25).

Another noteworthy aspect of this study is the confirmation of hypotheses through appropriate statistical tests, including paired and independent t-tests. These tests demonstrated with 95% confidence that the mean differences in both FBS and HbA1c between the exercise and control groups were statistically significant (Sig < 0.05). Such rigorous statistical analysis adds to the credibility of the findings.

However, like other studies, this research faced some limitations. First, the relatively small sample size limits the generalizability of the results to all women with type 2 diabetes. Second, despite efforts to control nutrition, factors such as diet, sleep, and stress levels might have influenced the outcomes. Additionally, only one type of intervention (moderate-intensity aerobic exercise) was applied, without including resistance or combined training modalities. Future research should consider expanding the range of exercises and extending the duration of interventions to obtain more comprehensive results.

Overall, the findings of this study suggest that moderate-intensity aerobic exercise can be an effective and safe non-pharmacological strategy for managing type 2 diabetes, especially in middle-aged women. Besides aiding in blood glucose control, these exercises improve quality of life, reduce secondary complications, and promote general health. Therefore, healthcare professionals are encouraged to incorporate regular aerobic exercise into diabetes treatment plans and to prioritize education and motivation of patients in this regard.

Δ. Conclusion

The present study aimed to investigate the effect of moderate-intensity aerobic exercise on fasting blood sugar (FBS) and glycated hemoglobin (HbA1c) levels in women with type 2 diabetes. The results demonstrated that this type of exercise significantly reduced FBS and HbA1c levels in the exercise group compared to the control group. These findings suggest that moderate-intensity aerobic exercise can serve as an effective, safe, accessible, and low-cost non-pharmacological intervention to improve blood glucose control in patients with type 2 diabetes, particularly middle-aged women.

Considering that type 2 diabetes is a common chronic disease among middle-aged women and its poor control can lead to severe complications such as cardiovascular diseases, kidney failure, neuropathy, and vision problems, complementary therapeutic approaches like regular physical exercise play a vital role in disease management. Therefore, the findings of this study can provide a foundation for designing exercise-based intervention strategies for diabetic patients.

It is recommended that such physical activities be seriously incorporated into the treatment plans of these patients. In this regard, physicians, nurses, fitness trainers, and nutrition specialists can collaborate to include aerobic exercise in individual or group treatment programs for diabetic patients to benefit from improved glycemic control. Furthermore, health centers, diabetes associations, and public health organizations are encouraged to raise awareness about the positive effects of exercise through educational courses, counseling sessions, and practical workshops, motivating patients toward regular and purposeful physical activity.

Additionally, integrating physical activity, especially aerobic exercises, into national diabetes prevention programs can serve as a scientific and effective strategy to reduce the prevalence of the disease.

Since the present study was limited to a specific sample, a fixed intervention duration, and a particular type of exercise, future studies are recommended to include larger sample sizes, more diverse populations, and longer intervention periods. Moreover, exploring the effects of other exercise types such as resistance training, combined exercises, martial arts-based activities, continuous walking, or art-based physical activities like dance could provide a more comprehensive understanding of the role of exercise in diabetes management. Finally, conducting physiological studies focusing on biochemical, hormonal, and inflammatory mechanisms related to the effects of physical activity on glucose metabolism is also recommended to offer a clearer perspective on the role of exercise in managing and improving the condition of patients with type 2 diabetes.

Despite the significant and notable findings, several limitations should be considered when interpreting the results and generalizing them to other populations. Firstly, the sample size was relatively small, and the study was conducted only on women with type 2 diabetes in a specific geographical area, which limits the generalizability of the findings to other demographic groups including men or different regions. Secondly, there was no precise control over important influencing factors such as daily diet, psychological stress level, and sleep quality of participants, which might directly or indirectly affect blood glucose indices and influence the results. The intervention duration was also relatively short, preventing assessment of the long-term effects of aerobic exercise, thus

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Compliance with ethical standards

Conflict of interest None declared.

Ethical approval The ethical principles of this study were approved by the Ethics Committee of Islamic Azad University, Khorasgan Branch, under the code IR.IAU.KHUIH.1403.511. The study adhered to ethical standards including obtaining informed consent, ensuring participant privacy, and maintaining confidentiality. Considering the conditions and timing of questionnaire completion, participants were reminded to answer all questions and were free to withdraw from the study at any time.

Informed consent Informed consent was obtained from all participants.

Author contributions

Conceptualization: A.B.M, F.T, KH.J.D, E.B ;
Methodology: A.B.M, F.T, KH.J.D, E.B; Software: A.B.M, F.T, KH.J.D, E.B; Validation: A.B.M, F.T, KH.J.D, E.B;
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Investigation: A.B.M, F.T, KH.J.D, E.B; Resources: A.B.M, F.T, KH.J.D, E.B; Data curation: E.B ; Writing - original draft: A.B; Writing - review & editing: A.B ;
Visualization: A.B.M, F.T, KH.J.D, E.B; Supervision: A.B.M, F.T, KH.J.D, E.B; Project administration: M.M ,M.Gh, H.P; Funding acquisition: A.B.M, F.T, KH.J.D, E.B

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