Original Article

The Immediate Effects of Aerobic Exercise with and Without External Loads on Blood Glucose, Cardiovascular, Respiratory, and Body Temperature Indices in Type II Diabetic Patients

Sedigheh Sadat Naimi, PhD[1], Soulmaz Rahbar, PhD[2*], Mohammad Reza Asadi, PhD[2], Hojjat Radinmehr, PhD[2], Ailin Talimkhani, PhD[2], Amin Doosti-Irani, PhD[3], Gholam-Reza Hajvalie, MSc[4]

[1]*Physiotherapy Research Center, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran.*
[2]*Department of Physiotherapy, School of Rehabilitation Sciences, Hamadan University of Medical Sciences, Hamadan, Iran.*
[3]*Department of Epidemiology, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran.*
[4]*Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.*

Received 05 October 2022; Accepted 09 December 2022

Abstract

Background: *The long-term effects of aerobic exercise on the cardiorespiratory system have been studied extensively. This study aimed to evaluate the effects of aerobic exercise with and without external loads on blood glucose, cardiovascular, respiratory, and body temperature indices in patients with type II diabetes.*

Methods: *The present randomized control trial recruited participants from the Diabetes Center of Hamadan University through advertisement. Thirty individuals were selected and divided into an aerobic exercise group and a weighted vest group via block randomization. The intervention protocol included aerobic exercise on the treadmill (0 slopes) with an intensity of 50% to 70% of the maximum heart rate. The exercise program for the weighted vest group was identical to that of the aerobic group, except that the subjects wore a weighted vest.*

Results: *The mean age of the study population was 46.77±5.11 years in the aerobic group and 48±5.95 years in the weighted vest group. After the intervention, blood glucose in the aerobic group (167.07±72.48 mg/dL; P<0.001) and the weighted vest group (167.75±61.53 mg/dL; P<0.001) was decreased. Additionally, resting heart rate (aerobic: 96.83±11.86 bpm and vest: 94.92±13.65 bpm) and body temperature (aerobic: 36.20±0.83 ℃ and vest: 35.48±0.46 ℃) were increased (P<0.001). Decreased systolic (aerobic: 117.92±19.27 mmHg and vest: 120.91±12.04 mmHg) and diastolic (aerobic: 77.38±7.54 mmHg and vest: 82.5±11.32 mmHg) blood pressure and increased respiration rate (aerobic: 23.07±5.45 breath/min and vest: 22±3.19 breath/min) were seen in both groups but were not statistically significant.*

Conclusion: *One aerobic exercise session with and without external loads reduced blood glucose levels and systolic and diastolic blood pressure in our 2 study groups.*

J Teh Univ Heart Ctr 2023;18(1):39-45

[*]**Corresponding Author:** ***Soulmaz Rahbar,*** *Assistant Professor of Physiotherapy, Hamadan University of Medical Sciences, Department of Physiotherapy, School of Rehabilitation Sciences, Shaheed Fahmideh Street, Hamadan, Iran. 6517838736. Tel: +98 81 38381571. Fax: +98 81 38381572. E-mail: ptrahbar413@yahoo.com.*

This paper should be cited as: Naimi SS, Rahbar S, Asadi MR, Radinmehr H, Talimkhani A, Doosti-Irani A, et al. The Immediate Effects of Aerobic Exercise with and Without External Loads on Blood Glucose, Cardiovascular, Respiratory, and Body Temperature Indices in Type II Diabetic Patients. J Teh Univ Heart Ctr 2023;18(1):39-45.

Keywords: *Exercise; Diabetes mellitus; Blood glucose; Blood pressure*

Introduction

Type II diabetes mellitus, one of the most common metabolic disorders, is caused by defective insulin secretion by pancreatic β-cells and tissue insulin resistance.[1] Type II diabetes accounts for 85% to 95% of all diabetes cases in the world due to lifestyle.[2] The latest estimates in 2017 indicated that 451 million people the world over had diabetes, with the figure projected to have risen to 693 million by 2045.[3] Diabetes imposes a significant burden on society in terms of expenses, premature death, and intangible costs in reduced quality of life.[4]

The salient complications of chronic hyperglycemia in patients with type II diabetes are microvascular (retinopathy, nephropathy, and neuropathy) and macrovascular, both of which can cause damage to various systems, leading to debilitating and health-threatening complications. Further, diabetes increases the risk of cardiovascular disease in patients by 2 to 4 times.[5]

Physical activity is a simple and inexpensive intervention to prevent diabetes or decelerate the process of diabetes. Exercise is the cornerstone of diabetes treatment. The 2018 Diabetes Standards recommend that individuals with type I and type II diabetes exercise 150 minutes a week with moderate to severe intensity.[6] Skeletal muscle is responsible for glucose consumption after meals and glucose transport. Glucose transport is primarily carried out by glucose transporter carrier proteins. Exercise causes this protein to move from inside the cell to the plasma membrane, leading to glucose consumption.[7] Type II diabetes is followed by arterial hypertension, autonomic dysfunction, and endothelial dysfunction. Endothelial dysfunction is affected by vasodilators, such as prostaglandins, nitric oxide, bradykinins, and kallikreins. Thus, exercise may produce endothelial repair and improve hypertension by producing these substances.[8] Aerobic exercise lowers blood pressure, augments insulin sensitivity, controls glucose, improves lipoprotein profile, and controls weight in type II diabetes. Recent evidence suggests that aerobic activity is associated with reduced cardiovascular risk and mortality.[6] Randomized controlled studies have reported that resistance exercise decreases insulin resistance, glycosylated hemoglobin (HbA1c), and fasting glucose by muscle hypertrophy in patients with type II diabetes.[9]

Various studies have examined the effects of various types of exercise on controlling blood sugar and arterial blood pressure. Exercises performed in various articles include aerobic,[10] resistance,[11] and aerobic and resistance combined.[10, 12, 13] The intensity of exercise used in different studies varies significantly, from 65% to 60% of the reserve heart rate for aerobic exercise. The intensity required for resistance exercise starts from a 1-repetition maximum (RM) of 50% to 30% and reaches a 1RM of 80% to 70% at the end[14] with a target heart rate of 65%.[15] Based on the Karvonen formula,[12] a 1RM of 60% to 50% (in the first week) can be increased in intensity to a 1RM of 85% to 75%.[11] Depending on activity or inactivity during 6 months,[16] improvements can be made in the intensity of swimming, walking,[17] and daily walking[18] up to between 65% and 85% of the maximum heart rate.[14]

Despite the positive effects of exercise on patients with diabetes, only a few such patients are likely to adhere to the exercise regimen. Significant barriers such as lack of knowledge about the need for exercise, the high cost of fitness centers, lack of time, hypoglycemia risk, and psychological problems are some of the reasons why patients with diabetes might not adhere to their exercise regimen.[19]

Many studies have applied multi-session protocols in diabetic patients,[10] while a single exercise session increases insulin sensitivity in obese individuals.[16] The advantages of the short protocol are its positive effects on the cardiac structure and function (central adaptation), myocardial glycolytic activity (peripheral adaptation), the regulation of metabolic gene expression in type II diabetes, and the control of blood sugar and HbA1c in the least time.[20] Recent evidence suggests the positive impact of acute exercise on systemic inflammatory mediators on immune cells regardless of weight or fat loss.[21] In a study by Cockcroft et al,[22] in a 24-hour period, the average blood glucose level was lower for all participants in the acute exercise condition. The novelty of the present study is the effect of a single exercise session with the standard protocol of the American Association (50%–70% of the maximum heart rate)[23] on blood glucose, which has scarcely been studied earlier. Additionally, none of the previously published studies has addressed the use of a weighted vest as a combined aerobic and resistance exercise.

In the current study, we aimed to investigate the immediate effects of 2 exercise protocols (aerobic exercise and aerobic exercise with external loads) on blood glucose and systolic and diastolic blood pressure in patients with type II diabetes. Although the positive effects of both exercise protocols have been proven, the current research aimed to determine which one was superior regarding its effects on the indicators commonly evaluated. The advantage of this study is that we had an aerobic exercise group with external loads using a weighted vest. We hypothesized that if the vest protocol proved superior, it could be simulated as a backpack, a convenient and cost-effective method to evaluate all type II diabetic patients.

Methods

The statistical population of this study comprised patients with diabetes referred to the Diabetes Center of Hamadan University. The study protocol was approved by the Research Ethics Committee of Hamadan University of Medical Sciences (ethics code: IR.UMSHA.REC.1399.049). The study was registered as a clinical trial study on the Iranian Registry of Clinical Trials (registration ID in IRCT: IRCT20190202042581N3, www.irct.ir). Individuals with type II diabetes, eligible for entry criteria and without exit criteria, were divided into an aerobic exercise group and an aerobic exercise group with external loads for evaluation. The sampling method was easy, but the samples were assigned to the groups randomly using block randomization. This study was a single-blinded randomized trial; in other words, the outcome assessor was unaware of the assigned treatment of the patients. The eligibility criteria included a disease duration of between 2 and 10 years, age between 40 and 60 years, a body mass index of between 20 and 30, an HbA1c level of 10% to 6%, no hypertension, no history of cardiovascular disease,[17, 24] no history of musculoskeletal diseases,[24] no history of other metabolic diseases,[24] no retinopathy,[12] no urea protein or kidney failure,[10, 12, 13, 17] no insulin use,[11] no foot ulcers, and no severe peripheral neuropathy. The exclusion criteria included not using β-blockers before the exercise test and feeling tired (considering that the patient's ability and not feeling tired constituted a prerequisite). The Borg scale was used. Based on the 20-point criterion, the exercise test is to be terminated when the patient says 16 and above. Furthermore, feeling short of breath and exhibiting hypoglycemia symptoms during the exercise test were other indicators for the exercise test termination. The study participants were asked not to make any changes in the type of medicine, nutrition, and activity before entering the study. The required sample size for the detection of the effects of the exercise test was calculated as 12 individuals in each group. Based on a study by Maiorana et al,[25] the effect size and its standard deviation were 1.3 and 1.8, respectively. Type I (α) and type II (β) errors were considered to be 0.05 and 0.1, respectively.

Considering the possibility of patient exclusion from the study for any reason, we sought to reduce the adverse effects by considering the sample size in each group to be 15 patients. Finally, due to problems such as acute low back pain, acute knee pain, and fear of falling off the treadmill, 13 patients participated in the aerobic exercise group and 12 in the weighted vest group. Diabetes was confirmed by an endocrinologist following the standards of the American Diabetes Association.[26] A cardiologist examined the patients with type II diabetes thoroughly. After meeting the inclusion criteria and undergoing an exercise test to ensure that they had no vascular obstruction, the patients entered the study voluntarily. They exhibited no ST depression, no drops in blood pressure, and no symptoms during the exercise test and the intervention protocol. Before the intervention, anthropometric characteristics, including weight and body mass index, were measured in all the participants, who subsequently provided a written consent form to participate in the study. The patients with type II diabetes were randomly divided into 2 groups: aerobic and aerobic with external loads. In the former group, the therapeutic intervention was walking on a treadmill for 30 minutes. The intensity of physical activity was determined according to the standards of the American Diabetes Association in patients with diabetes, 50% to 70% of the maximum heart rate. The intensity range increased from 50% to 70% during this session. Maximum heart rate was obtained through exercise testing at Farshchian Heart Hospital in Hamadan. The target heart rate in the patients was calculated via the Karvonen formula: HRtarget = HR rest + 50–70% (HRmax - HR rest). In the latter group, a weighted vest was used to apply more force to the cardiorespiratory system while walking on the treadmill. The weights utilized were distributed inside the patient's pockets at the back and bottom to prevent flexural torque and to create a backpack simulation for future recommendation to other patients with diabetes. The weights used were 200 to 300 g and were easy to put in and out of pockets. The weight was 5% of body weight in accordance with a study by Roghani et al.[27]

At the beginning and the end of 30 minutes of exercise, blood pressure was measured with a digital sphygmomanometer (Omron RS2 digital pressure gauge, China), and blood glucose was measured with a glucose meter (Accu-Chek Performa glucometer, USA). A physiotherapist measured the participants' body temperature with a thermometer (Omron GentleTemp 520). A digital thermometer was placed in the ear, and the temperature was read on the digital screen. A heart rate monitor (Beurer PO60 digital pulse meter, Germany) was drawn upon during the entire protocol execution time.

Categorical variables were reported as frequencies and percentages, and continuous variables were reported as means and standard deviations (SDs). The Shapiro–Wilk normality test was used to check the normality of the outcomes. Due to the normality of the data, the parametric test was employed for data analysis. Differences in resting heart rate, blood sugar, systolic and diastolic blood pressure, temperature, and respiratory rate before and after the intervention were calculated. Because the correlations between the values of the variables before and after the intervention exceeded 0.5, the change score approach was applied to compare the outcomes between the groups. The t test was carried out to compare differences in the mentioned outcomes between the groups. The statistical significance was considered to be 0.05. The Stata 14.2 software (StataCorp, TX, US) was used for data analysis.

Results

The present study enrolled 30 patients between 40 and 60 years of age with type II diabetes. The participants were randomly divided into 2 groups: aerobic (n=15) and aerobic with external loads (n=15). Two patients in the aerobic group and 3 patients in the weighted vest group were excluded from the study due to problems. Finally, 25 patients (13 in the aerobic group and 12 in the aerobic group with external loads) completed the study. The study participants' demographic characteristics at the beginning of the intervention are presented in Table 1. Table 2 shows that after the intervention, blood glucose in the aerobic group (mean±SD =167.07±72.48 mg/dL; P<0.001) and the weighted vest group (mean±SD =167.75±61.53 mg/dL; P<0.001) was decreased. Furthermore, resting heart rate (aerobic: 96.83±11.86 bpm and vest: 94.92±13.65 bpm) and body temperature (aerobic: 36.20±0.83 °C and vest: 35.48±0.46 °C) were increased (P<0.001). Decreased systolic (aerobic: 117.92±19.27 mmHg and vest: 120.91±12.04 mm Hg) and diastolic (aerobic: 77.38±17.54 and vest: 82.5±11.32) blood pressure and increased respiration rate (aerobic: 23.07±5.45 breath/min and vest: 22±3.19 breath/min) were seen in both groups but were not statistically significant. The intergroup comparison showed no difference between the effects of the protocol type (Table 3). Figure 1 presents the various stages of this study in a CONSORT diagram. This trial study met the criteria in the CONSORT checklist.

Table 1. Basic characteristics of the aerobic exercise and weighted vest groups (mean ±standard deviation)

Variable	Aerobic Group (n=13)	Weighted Vest Group (n=12)	*P*
Age (y)	46.77±5.11	48.00±5.95	0.583
Weight (kg)	75.63±13.52	74.73±8.35	0.843
BMI (kg/m^2)	27.64±3.98	26.65±2.98	0.461
Disease duration (y)	4.61±2.14	5.41±2.74	0.422
FBS (mg/dL)	167.54±67.02	156.66±39.16	0.629
HbA1c (%)	7.27±1.27	7.74±1.57	0.419

BMI, Body mass index; FBS, Fasting blood sugar; HbA1c, Glycosylated hemoglobin

Table 2. Indicators of blood sugar, heart rate, respiration, and body temperature before and after a session of the exercise protocol

Variable	Aerobic Group (n=13)		*P*	Weighted Vest Group (n=12)		*P*
	After	Before		After	Before	
Blood sugar (mg/dL)	167.07±72.48	200.76±70.04	<0.001	167.75±61.53	217.00±65.19	<0.001
Rest heart rate (bpm)	94.92±13.65	83.4±10.92	<0.001	96.83±11.86	82.25±9.56	0.001
SBP (mmHg)	117.92±19.27	124.15±18.97	0.384	120.91±12.04	124.08±13.60	0.065
DBP (mmHg)	77.38±17.54	80.46±13.02	0.403	82.50±11.32	79.83±8.99	0.359
Temperature (°C)	36.20±0.83	35.92±0.88	0.048	35.77±0.65	35.48±0.46	0.049
Respiratory rate (breath/min)	23.07±5.45	21.70±5.57	0.491	22،00±3.19	21،00±6.41	0.557

SBP, Systolic blood pressure; DBP, Diastolic blood pressure

Table .3 Comparisons of mean differences in blood glucose ,cardiac ,respiratory ,and body temperature indices after the exercise protocol

Variable	Aerobic Group (n=13)		Weighted Vest Group (n=12)		*P*
	Mean difference	Standard deviation	Mean difference	Standard deviation	
Blood sugar (mg/dL)	-33.69	19.94	-49.25	28.79	0.127
Rest heart rate (bpm)	11.08	9.77	14.58	5.97	0.295
SBP (mmHg)	-6.23	11.09	-3.16	12.10	0.515
DBP (mmHg)	-3.07	11.63	2.66	10.62	0.211
Temperature (°C)	0.28	0.47	0.29	0.45	0.970
Respiratory rate (breath/min)	1.37	8.18	1	4.86	0.893

SBP, Systolic blood pressure; DBP, Diastolic blood pressure

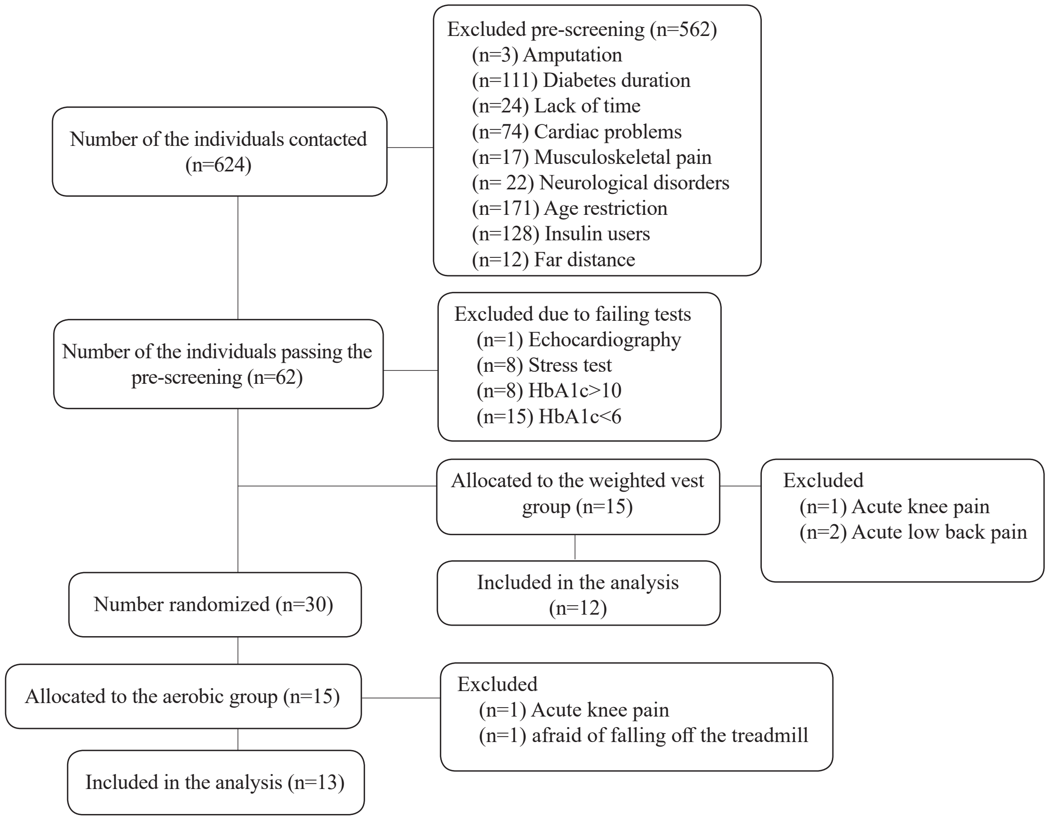

Figure 1. The image illustrates the CONSORT diagram.

Discussion

The present study investigated the effects of 1 session of aerobic and combined aerobic and resistance protocol on the biochemical glucose index and the vital indices of systolic and diastolic blood pressure, resting heart rate, respiration, and body temperature. The results showed that aerobic and combined exercise significantly reduced blood glucose levels and significantly increased heart rate and body temperature compared with the values before the exercise test.

Although a decrease in systolic and diastolic blood pressure and an increase in respiratory rate were observed in both groups, the change in these 2 indicators was not significant. One of the hallmarks of diabetes is hyperglycemia. The cause of hyperglycemia is impaired insulin production, insulin function, or both.[28] Exercise exerts a considerable impact on glucose control. In terms of duration, short-term exercise,[29, 30] medium-term exercise (for 1 month, 2 months, and 3 months),[31] and long-term exercise (for 6 months or more) are used.[11, 32] It is challenging to have patients cooperate in physiotherapy clinics for long-term exercise, and we witness the interruption of exercise programs, the aggravation of diabetes symptoms, and the complete failure of rehabilitation programs. Therefore, in the present study, a single session of the protocol was considered to control the indicators.

Walking on a treadmill is a dynamic exercise in which muscle contraction occurs. In the aerobic group with external loads and muscle contraction, the weights inside the vest cause more muscle contraction, especially type II fibers, than in the group without a vest.[27] Various studies have assessed the effects of short-term exercise on blood glucose index. Praet et al[33] examined the effects of combined aerobic exercise on cycling and acute resistance in patients with insulin-dependent type II diabetes. They measured glucose at different intervals. Three hours after the exercise test, glucose levels were lower than before the test. However, after 24 hours, no significant difference was observed in terms of glucose content. One group participated in the study in the prep study, and no comparison was made. In a study on patients with paraplegia with a history of type II diabetes intervention, Farkas et al[34] measured blood glucose immediately after exercise and 24 hours after exercise using manual ergometry at 75% of maximal oxygen consumption. Immediately after the exercise test, a decrease in blood glucose was observed, which is in line with the present study. While no change was observed 24 hours after the exercise test, the authors stated that continued exercise was essential to increase insulin sensitivity. Newsom et al[23] investigated the effects of a single exercise session on insulin sensitivity. After a moderate exercise session, insulin sensitivity was increased compared with the control group, confirming the impact of exercise on hypoglycemia in the present study. Increased glucose uptake following exercise is due to decreased insulin resistance. The increase in insulin resistance in type II diabetes is due to the decreased expression of glucose-4 transporter protein in muscle and possibly mitochondrial dysfunction. The transfer of the transporter protein from the cell to the plasma membrane is the basis of glucose uptake into skeletal muscle. This process enhances the effectiveness of insulin. Exercise also augments mitochondrial capacity in skeletal muscle cells, increases mitochondrial oxidase activity, and regulates intra-mitochondrial fat, improving mitochondrial function. Increased mitochondrial function is associated with glucose oxidation and utilization.[35] Kennedy investigated the cause of increased insulin sensitivity. Five patients with type II diabetes and 5 healthy individuals underwent a biopsy of the vastus lateralis muscle after a cycling session with an intensity of 70% to 60% of the maximum oxygen consumption in terms of the amount of glucose 1 in the plasma membrane. After a single exercise session in both groups, an increase in the glucose 1 carrier was observed in the plasma membrane of the muscle; nonetheless, a comparison between the 2 groups showed that this increase was not significant. The results of their slow study confirm the positive effects of a single exercise session in the present study.[36]

The next indicator is systolic and diastolic blood pressure. Bailey et al[37] reported that high-intensity exercise reduced vascular function and increased blood pressure. In a study of hypertension, Quinn et al[38] observed a decrease in systolic and diastolic blood pressure after an exercise session of 50% to 75% of maximal oxygen consumption. In the present study, the same positive result was obtained after exercise. However, there was a difference in the type of exercise protocol performed in this study according to the standards of the American Diabetes Association.

The mechanism of hypotension after exercise can be explained in different ways. For instance, exercise increases the activity of the autonomic system and, consequently, reduces vascular resistance, lowering systolic and diastolic blood pressure. Moreover, exercise reduces insulin resistance and, thus, lowers blood pressure. It can also be claimed that improving the function of the vascular endothelial layer after exercise also leads to a reduction in blood pressure.[39] Furthermore, the release of vasodilators, which improves arterial vasodilation, leads to a decrease in blood pressure. It is also noteworthy that baroreflex activity, with a negative self-regulatory role, lowers blood pressure after exercise.[40]

The essential indicators evaluated in the current study were respiratory rate and body temperature. Respiratory rate is one of the vital signs providing information about the prognosis of cardiac arrest and the diagnosis of acute pneumonia. Respiratory rate is also one of the best fatigue and physical exertion markers during exercise.[41]

Our study participants had diabetes; accordingly, the results cannot be generalized to other diseases. In addition, we could not fully control the participants in terms of nutrition.

We suggest that the effects of a single exercise session on the mentioned indicators be examined in the days that follow an exercise test to determine the long-term effects of exercise. The drop in blood glucose in the current investigation, albeit statistically significant, was not of clinical significance. It would, therefore, be desirable to choose a more sizable study population or redo tests an hour after exercise.

Acknowledgments

This research was approved and supported by Hamadan University of Medical Sciences (9902231143).

References

1. Galicia-Garcia U, Benito-Vicente A, Jebari S, Larrea-Sebal A, Siddiqi H, Uribe KB, Ostolaza H, Martín C. Pathophysiology of Type 2 Diabetes Mellitus. Int J Mol Sci 2020;21:6275.
2. Pan B, Ge L, Xun YQ, Chen YJ, Gao CY, Han X, Zuo LQ, Shan HQ, Yang KH, Ding GW, Tian JH. Exercise training modalities in patients with type 2 diabetes mellitus: a systematic review and network meta-analysis. Int J Behav Nutr Phys Act 2018;15:72.
3. Zibaeenezhad MJ, Sayadi M, Mohammadi SS, Khorshidi S, Hadiyan E, Rasouli N, Karimi-Akhormeh A, Razeghian-Jahromi I. The Impact of Diabetes Mellitus on Clinical Outcomes after Percutaneous Coronary Intervention with Different Stent Sizes. J Tehran Heart Cent 2022;17:207-214.
4. American Diabetes Association. Economic Costs of Diabetes in the U.S. in 2017. Diabetes Care 2018;41:917-928.
5. Viigimaa M, Sachinidis A, Toumpourleka M, Koutsampasopoulos K, Alliksoo S, Titma T. Macrovascular Complications of Type 2 Diabetes Mellitus. Curr Vasc Pharmacol 2020;18:110-116.
6. Wahl MP, Scalzo RL, Regensteiner JG, Reusch JEB. Mechanisms of Aerobic Exercise Impairment in Diabetes: A Narrative Review. Front Endocrinol (Lausanne) 2018;9:181.
7. Adams OP. The impact of brief high-intensity exercise on blood glucose levels. Diabetes Metab Syndr Obes 2013;6:113-122.
8. Simões HG, Asano RY, Sales MM, Browne RA, Arsa G, Motta-Santos D, Puga GM, Lima LC, Campbell CS, Franco OL. Type 2 diabetes elicits lower nitric oxide, bradykinin concentration and kallikrein activity together with higher DesArg(9)-BK and reduced post-exercise hypotension compared to non-diabetic condition. PLoS One 2013;8:e80348.
9. Shimomura M, Horii N, Fujie S, Inoue K, Hasegawa N, Iemitsu K, Uchida M, Iemitsu M. Decreased muscle-derived musclin by chronic resistance exercise is associated with improved insulin resistance in rats with type 2 diabetes. Physiol Rep 2021;9:e14823.
10. Maiorana A, O'Driscoll G, Goodman C, Taylor R, Green D. Combined aerobic and resistance exercise improves glycemic control and fitness in type 2 diabetes. Diabetes Res Clin Pract 2002;56:115-123.
11. Cohen ND, Dunstan DW, Robinson C, Vulikh E, Zimmet PZ, Shaw JE. Improved endothelial function following a 14-month resistance

exercise training program in adults with type 2 diabetes. Diabetes Res Clin Pract 2008;79:405-411.
12. Okada S, Hiuge A, Makino H, Nagumo A, Takaki H, Konishi H, Goto Y, Yoshimasa Y, Miyamoto Y. Effect of exercise intervention on endothelial function and incidence of cardiovascular disease in patients with type 2 diabetes. J Atheroscler Thromb 2010;17:828-833.
13. Maiorana A, O'Driscoll G, Cheetham C, Dembo L, Stanton K, Goodman C, Taylor R, Green D. The effect of combined aerobic and resistance exercise training on vascular function in type 2 diabetes. J Am Coll Cardiol 2001;38:860-866.
14. Bacchi E, Negri C, Zanolin ME, Milanese C, Faccioli N, Trombetta M, Zoppini G, Cevese A, Bonadonna RC, Schena F, Bonora E, Lanza M, Moghetti P. Metabolic effects of aerobic training and resistance training in type 2 diabetic subjects: a randomized controlled trial (the RAED2 study). Diabetes Care 2012;35:676-682.
15. Melton CE, Tucker PS, Fisher-Wellman KH, Schilling BK, Bloomer RJ. Acute exercise does not attenuate postprandial oxidative stress in prediabetic women. Phys Sportsmed 2009;37:27-36.
16. Wildman RP, Schott LL, Brockwell S, Kuller LH, Sutton-Tyrrell K. A dietary and exercise intervention slows menopause-associated progression of subclinical atherosclerosis as measured by intima-media thickness of the carotid arteries. J Am Coll Cardiol 2004;44:579-585.
17. Meyer AA, Kundt G, Lenschow U, Schuff-Werner P, Kienast W. Improvement of early vascular changes and cardiovascular risk factors in obese children after a six-month exercise program. J Am Coll Cardiol 2006;48:1865-1870.
18. Pahkala K, Heinonen OJ, Simell O, Viikari JS, Rönnemaa T, Niinikoski H, Raitakari OT. Association of physical activity with vascular endothelial function and intima-media thickness. Circulation 2011;124:1956-1963.
19. Jenkins DW, Jenks A. Exercise and Diabetes: A Narrative Review. J Foot Ankle Surg 2017;56:968-974.
20. Gibala MJ, Little JP, Macdonald MJ, Hawley JA. Physiological adaptations to low-volume, high-intensity interval training in health and disease. J Physiol 2012;590:1077-1084.
21. Collao N, Rada I, Francaux M, Deldicque L, Zbinden-Foncea H. Anti-Inflammatory Effect of Exercise Mediated by Toll-Like Receptor Regulation in Innate Immune Cells - A Review. Int Rev Immunol 2020;39:39-52.
22. Cockcroft EJ, Moudiotis C, Kitchen J, Bond B, Williams CA, Barker AR. High-intensity interval exercise and glycemic control in adolescents with type one diabetes mellitus: a case study. Physiol Rep 2017;5:e13339.
23. Newsom SA, Everett AC, Hinko A, Horowitz JF. A single session of low-intensity exercise is sufficient to enhance insulin sensitivity into the next day in obese adults. Diabetes Care 2013;36:2516-2522.
24. Spence AL, Carter HH, Naylor LH, Green DJ. A prospective randomized longitudinal study involving 6 months of endurance or resistance exercise. Conduit artery adaptation in humans. J Physiol 2013;591:1265-1275.
25. Maiorana AJ, Naylor LH, Exterkate A, Swart A, Thijssen DH, Lam K, O'Driscoll G, Green DJ. The impact of exercise training on conduit artery wall thickness and remodeling in chronic heart failure patients. Hypertension 2011;57:56-62.
26. American Diabetes Association. Standards of medical care in diabetes--2014. Diabetes Care 2014;37 Suppl 1:S14-80.
27. Roghani T, Torkaman G, Movasseghe S, Hedayati M, Goosheh B, Bayat N. Effects of short-term aerobic exercise with and without external loading on bone metabolism and balance in postmenopausal women with osteoporosis. Rheumatol Int 2013;33:291-298.
28. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care 2010;33 Suppl 1(Suppl 1):S62-69.
29. McConell GK, Lee-Young RS, Chen ZP, Stepto NK, Huynh NN, Stephens TJ, Canny BJ, Kemp BE. Short-term exercise training in humans reduces AMPK signalling during prolonged exercise independent of muscle glycogen. J Physiol 2005;568(Pt 2):665-676.
30. Yokoyama H, Emoto M, Fujiwara S, Motoyama K, Morioka T, Koyama H, Shoji T, Inaba M, Nishizawa Y. Short-term aerobic exercise improves arterial stiffness in type 2 diabetes. Diabetes Res Clin Pract 2004;65:85-93.
31. Rahbar S, Naimi SS, Reza Soltani A, Rahimi A, Akbarzadeh Baghban A, Khorami N. Are Twenty-Four Sessions of Aerobic Exercise Sufficient for Improving Cardiac Parameters in Diabetes Mellitus? A Randomized Controlled Trial. J Tehran Heart Cent 2018;13:43-51.
32. Fakhry F, Spronk S, de Ridder M, den Hoed PT, Hunink MG. Long-term effects of structured home-based exercise program on functional capacity and quality of life in patients with intermittent claudication. Arch Phys Med Rehabil 2011;92:1066-1073.
33. Praet SF, Manders RJ, Lieverse AG, Kuipers H, Stehouwer CD, Keizer HA, van Loon LJ. Influence of acute exercise on hyperglycemia in insulin-treated type 2 diabetes. Med Sci Sports Exerc 2006;38:2037-2044.
34. Farkas GJ, Swartz AM, Gorgey AS, Berg AS, Gater DR. Acute exercise improves glucose effectiveness but not insulin sensitivity in paraplegia. Disabil Rehabil 2022;44:4656-4662.
35. Yang D, Yang Y, Li Y, Han R. Physical Exercise as Therapy for Type 2 Diabetes Mellitus: From Mechanism to Orientation. Ann Nutr Metab 2019;74:313-321.
36. Kennedy JW, Hirshman MF, Gervino EV, Ocel JV, Forse RA, Hoenig SJ, Aronson D, Goodyear LJ, Horton ES. Acute exercise induces GLUT4 translocation in skeletal muscle of normal human subjects and subjects with type 2 diabetes. Diabetes 1999;48:1192-1197.
37. Bailey TG, Perissiou M, Windsor MT, Schulze K, Nam M, Magee R, Leicht AS, Green DJ, Greaves K, Golledge J, Askew CD. Effects of acute exercise on endothelial function in patients with abdominal aortic aneurysm. Am J Physiol Heart Circ Physiol 2018;314:H19-H30.
38. Quinn TJ. Twenty-four hour, ambulatory blood pressure responses following acute exercise: impact of exercise intensity. J Hum Hypertens 2000;14:547-553.
39. Fagard RH, Cornelissen VA. Effect of exercise on blood pressure control in hypertensive patients. Eur J Cardiovasc Prev Rehabil 2007;14:12-17.
40. Oliveira R, Barker AR, Debras F, O'Doherty A, Williams CA. Mechanisms of blood pressure control following acute exercise in adolescents: Effects of exercise intensity on haemodynamics and baroreflex sensitivity. Exp Physiol 2018;103:1056-1066.
41. Nicolò A, Massaroni C, Schena E, Sacchetti M. The Importance of Respiratory Rate Monitoring: From Healthcare to Sport and Exercise. Sensors (Basel) 2020;20:6396.