Research Paper

The Effect of Concurrent Training on Some Cardiovascular Risk Factors, Serum Estradiol and Physical Fitness Indicators in Overweight Women With Type 2 Diabetes

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Citation Azmand F, Haghighi AH, Askari R, Shahrabadi H. The Effect of Concurrent Training on Some Cardiovascular Risk Factors, Serum Estradiol and Physical Fitness Indicators in Overweight Women With Type 2 Diabetes. Iranian Journal of Health Sciences. 2024; 12(1):59-68. http://dx.doi.org/10.32598/ijhs.12.1.1000.1

doi http://dx.doi.org/10.32598/ijhs.12.1.1000.1

ABSTRACT

Background and Purpose: Considering that diabetic patients have low physical fitness and are prone to cardiovascular diseases, there is a need to conduct studies for the prevention and treatment of these diseases. The present study investigates the effect of concurrent training (CT) on some cardiovascular risk factors, serum estradiol, and physical fitness indicators in overweight women with type 2 diabetes.

Materials and Methods: The research method was quasi-experimental with a pre-test and post-test design. A total of 30 women with type 2 diabetes were randomly divided into CT and control (CON) groups. Concurrent training was performed for 8 weeks and 3 sessions per week. The CT program included resistance training with elastic bands, running with an intensity of 70%-85% of the maximum heart rate, and skipping rope training with 40-45 jumps per minute. Forty-eight hours before and after the intervention, blood samples were collected from all participants in a fasting state to evaluate serum glucose, triglyceride, cholesterol levels, and estradiol. The VO_2 max and upper body and lower body strength indicators were also assessed in all participants. The data was analyzed using the statistical method of ANOVA with repeated measures.

Results: The results showed a significant increase in VO_2 max, serum estradiol, upper and lower body muscle strength, and a significant decrease in serum triglyceride and glucose in the CT group compared to the CON group ($P<0.05$). No significant difference was observed in low-density lipoprotein/high-density lipoprotein ratio and total cholesterol ($P>0.05$).

Conclusion: Eight weeks of concurrent training can improve physical fitness indicators and some cardiovascular risk factors in overweight women with type 2 diabetes.

Keywords: Exercise, Heart disease risk factors, Estradiol, Diabetes mellitus

Article info:

Received: 05 Nov 2023

Accepted: 25 Dec 2023

Available Online: 01 Jan 2024

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Introduction

Diabetes is one of the chronic diseases associated with increased blood glucose levels and body metabolic disorders due to a lack or decrease in insulin function [1]. Type 2 diabetes is a chronic disease that is spreading at an alarming rate in the world. Obesity and diabetes have increased significantly in developed and developing countries [2]. According to the World Health Organization (WHO), the number of people with diabetes will increase to 366 million by 2030 [3].

Type 2 diabetes is often associated with cardiovascular disease risk factors: Blood pressure, dyslipidemia, obesity, and lack of physical activity. The leading cause of death in these patients is cardiovascular disease, which accounts for 65% of all deaths among these patients [4]. Lipid disorders significantly increase the risk of cardiovascular diseases and other diseases related to diabetes. High levels of total cholesterol, triglyceride, low-density lipoprotein (LDL), glycosylated hemoglobin (HbA1c), high blood pressure, low high-density lipoprotein (HDL) concentration, and increased body mass index (BMI) are significantly associated with cardiovascular diseases [5]. Also, changes in hormonal patterns in menopause, including a decrease in estradiol levels, a relative increase in androgens, and an increase in visceral fat associated with glycemic traits, rising the risk of type 2 diabetes [6].

Exercise training can have essential effects on preventing and treating obesity and related diseases [7]. Studies have shown that physical activity and exercise training are beneficial by empowering the body's skeletal muscles to take more glucose from the blood without requiring insulin [8]. The role of regular physical activity, both in the primary prevention and the treatment of this disease, is well defined, and people with type 2 diabetes can benefit from the advantages of physical activity to control their blood glucose level, lipid profile, and body weight better [9]. Aerobic and resistance training are common non-medicinal methods in treating diabetic patients. Aerobic training is an activity with oxygen consumption that can increase glucose consumption in peripheral tissues and help increase insulin sensitivity. Resistance training is an anaerobic activity that exerts a certain resistance on a particular muscle group during exercise, which can increase muscle volume and glucose absorption and improve insulin sensitivity [10]. A combination of aerobic and resistance training, as recommended by current American Diabetes Association (ADA) guidelines, may be the most effective method for glucose and lipid control in type 2 diabetes [11]. However, the design of the best concurrent training (CT) method for diabetic patients is still unsettled.

Previous research has shown a relationship between low estrogen levels and type 2 diabetes [12]. According to previous research, in addition to cardiovascular benefits, CT increases lean mass. Clinical research also indicates better glycemic control in CT than in aerobic or resistance training alone [13]. In CT, two training methods are performed in one session, which is a suitable strategy due to the time limitations of patients [14]. Therefore, it is necessary to investigate the effect of CT on some cardiovascular risk factors, serum estradiol, and physical fitness indicators in overweight women with type 2 diabetes. It is assumed that CT will improve these indicators.

Materials and Methods

Study design

The current research method was quasi-experimental with a pre-test and post-test design with a control (CON) group, implemented in 2019.

Study participants

The convenience sampling technique was used to select the study samples. The G*Power software, version 3.1.9.4 was used to derive a sample size of 20 based on a two-tailed procedure, an effect size of 0.60 in VO_2 max based on the study of Motahari Rad et al. [15], a significance level of 0.05, and a statistical power value of 0.80. Although the researchers calculated the sample size to be 20, considering that the participants in the present study were overweight women with type 2 diabetes and a possibility of dropping the sample size, the researchers selected 30 to start the study. So, 32 women with type 2 diabetes were selected out of 40 who were referred to health centers in Kashmar City, Iran, for treatment according to the inclusion criteria such as having a blood glucose level of less than 250 mg/dL, having a history of type 2 diabetes for more than 5 years, no history of cardiovascular diseases, no regular physical activity in the last 6 months, and no smoking and alcohol consumption. After explaining the aims and methods of the study, 2 out of 32 withdrew due to their unwillingness to participate, and the remaining participants completed the consent form. The participants were randomly divided into CT (n=16) and CON (n=14) groups. The exclusion criteria were as follows: Being more than 3 sessions absent from training, participating in exercise outside of the training protocol, and deciding on a specialist physician to stop the training program. According to Figure 1, ten participants out of 30 were excluded from the study during the intervention period due to personal reasons and a specialist physician's interruption of the training program. As a result, the post-test stage was conducted with 10 participants for each group.

Implementation method and measurements

The participants were invited to the gym to measure their height, weight, and physical fitness indicators 1 week before the start of the training program. The participants also were invited to a medical laboratory to check the biochemical indicators. After this stage, the participants of the CT group performed the training program for 8 weeks, and 48 hours after the last training session, blood samples were collected in a fasting state, and physical fitness indicators were taken from all the participants, similar to the pre-test stage. The participants were asked not to make any special changes in their diet during the intervention period and to report illness or any abnormal feelings.

Diagnosis of diabetics

An endocrinologist specialist diagnosed type 2 diabetes, and people are considered diabetic with a blood glucose level higher than 126 mg/dL, a 2-h blood glucose level higher than 200 mg/dL, or a HbA1c concentration of more than 6.5% [16].

Exercise protocol

The training program consisted of 8 weeks of CT performed in 3 sessions per week. Each exercise session consisted of 10 minutes of warm-up, 49-88 minutes of CT, which included 23-38 minutes of activity, 26-50 minutes of rest between sets, and 10 minutes of cooling down. The training program was designed based on the participants' physical characteristics and recommendations of sports coaches and previous studies [17]. The exercise training program included running, skipping rope, and resistance exercises with elastic bands (Table 1). The wrist pulse and metronome were used to control the running and skipping rope training intensity, respectively.

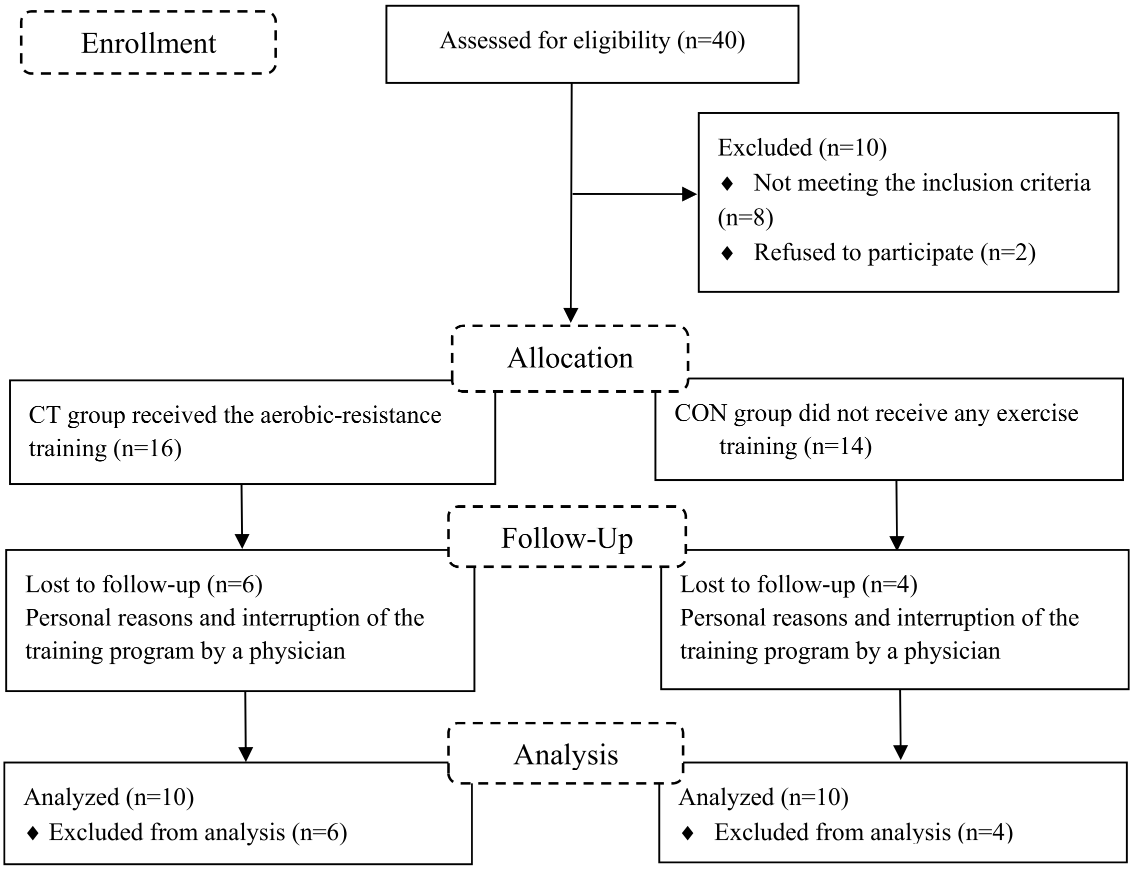

Figure 1. Flowchart of the study design

The rest period between sets was 60 seconds. To comply with the overload principle, the resistance of the elastics was increased in weeks 2, 4, 6, and 8.

Blood sampling

Blood samples (5 mL) were taken in the pre-test and post-test after 12-14 hours of fasting in a sitting position by the laboratory technician. The blood sample was kept at room temperature for 1 hour to clot; then, the clot was separated from the wall of the test tube and centrifuged at 3000 rpm for 15 minutes. All participants were asked not to do strenuous physical activity 2 days before the blood sampling. All measurements were conducted in a laboratory center in the pre-test and post-test phases. Fasting serum glucose, triglyceride, and cholesterol levels were measured using the Pars test kit manufactured in Iran with a 0.99 mg/dL sensitivity. The amount of serum estradiol was calculated using the Vidas kit manufactured in France using the immunofluorescence method with a sensitivity of 0.9 pg/mL.

Anthropometric status

Standing height without shoes was measured using tape (Tosan, China). Body weight was measured using a portable SECA scale to the nearest 0.1 kg (Seca 770, Hamburg, Germany). Body composition was also assessed using BMI.

Physical fitness indicators

The VO_2 max and upper and lower body strength indicators were investigated in the present study. Before measuring the physical fitness indicators, the participants got acquainted with the physical fitness tests. All safety issues were considered during measurements. The participants repeated each test twice, and their best performance was recorded by two experienced assessors.

The 1-mile Rockport walking test was used to measure maximum oxygen consumption. This test was carried out in dimensions of 35×45 m. The participants walked 20 laps at maximum speed, and then the running time was measured using a stopwatch [18].

VO_2 max (mL/kg/min) was estimated using the following equation: [132.853-(0.0769×body weight in lbs)-(0.3877×age in y)-(3.2649×time in min)-(0.1565×heart rate in beats/min)].

The arm curl test evaluates the strength of the arm flexor muscles. The participants to perform the test sat on a chair and were asked to lean their back against the back of the chair to avoid excessive body movements; then, with a weight of 2.27 kg, they performed the arm curl movement while the palm was facing up. The number of repetitions of elbow flexion and extension in 30 s was recorded for each individual [19].

Finally, the 30-s chair stand test evaluates the performance of the lower body muscles. The participants who performed the test sat in the middle of the chair without arms, with a seat height of 43.2 cm. In this position, the feet were placed on the floor at an angle slightly back from the knees, and the hands were crossed on the chest. At the signal "go", the participants rose to a full stand and then returned to the initial seated position. The number of sit-to-stand repetitions in 30 s was recorded for each individual [19].

Dietary analysis

The 24-h food recall questionnaire was used for 3 days in the first week of the training intervention and in the last week of the study to calculate calorie intake in order to control the confounding effect of the patient's diet. The data on food intake was analyzed with the use of Nutrition 4 software (First Databank, San Bruno, CA, USA).

Statistical analysis

The Shapiro-Wilk test was used to determine the normality of the data distribution. Analysis of variance with repeated measures was used to test the research hypotheses. The effect size of the independent samples was calculated by partial eta squared ($p\eta^2$). An effect size of 0.10 is considered small, 0.25 medium, and 0.40 large [20]. All statistical operations were performed using SPSS software, version 22 and the significance level of alpha was considered 0.05 in all tests.

Results

The number of participants at baseline was 30 (n=16 and 14 for CT and CON, respectively), which decreased to 20 (n=10 for CT and CON) in the follow-up phase. Age, height, weight, BMI, and history of diabetes of the CT group (n=10) were 54.10±3.11 y, 159.30±2.21 cm, 68.49±4.86 kg, 27.02±2.29 kg/m^2 and 8.20±2.30 y, respectively. These indices in the CON group (n=10) were 52.20±4.92 y, 161.10±4.92 cm, 75.71±6.33 kg, 29.14±1.46 kg/m^2, and 8.60±2.88 y, respectively. Significant differences in weight (P=0.010) and BMI (P=0.024) were observed between the two groups. Also, there were no significant differences between the two groups in age (P=0.315), height (P=0.304), and history of diabetes (P=0.735).

None of the participants were injured during the training protocol. The mean compliance percentage was calculated as a percentage of attendance sessions versus the total number of required sessions, which was 91.25%±4.99% for the CT group. The Mean±SD of the heart rate during running was reported as 125.57±2.38 beats/min.

The Mean±SD of daily caloric intake are given in Figure 2. The changes in daily calorie intake during the intervention period were not significantly different between CT and CON groups (F=0.041, P=0.841, $p\eta^2$=0.002).

The Mean±SD of serum estradiol level is given in Figure 3. The results of this study showed that an 8-week CT had a significant effect on serum estradiol levels in overweight women with type 2 diabetes (F=6.642, P=0.019, $p\eta^2$=0.270).

The analysis of variance (ANOVA) with repeated measures showed that CT significantly improved VO_2 max, arm curl, and 30-s chair stand (P<0.001, $p\eta^2$=0.749-0.940) (Table 2).

ANOVA with repeated measures showed that CT causes a significant decrease in serum triglyceride and fasting blood sugar (FBS) levels (P=0.015-0.019, $p\eta^2$=0.269-0.286). On the other hand, no significant changes were observed in the indices of LDL/HDL ratio and serum total cholesterol (P=0.079-0.143, $p\eta^2$=0.115-0.162) (Table 3).

Discussion

The purpose of this study was to investigate the effect of CT on some cardiovascular risk factors, as well as serum estradiol and physical fitness indicators in overweight women with type 2 diabetes. The results showed that CT improves physical fitness indicators, including VO_2 max and upper body and lower body muscle strength. Some biochemical indicators, such as serum estradiol, increased, but serum triglyceride and glucose decreased significantly. No significant changes were observed in the LDL/HDL ratio and total cholesterol.

In the present study, a significant increase (52.32%) in VO_2 max was observed in women with type 2 diabetes after 8 weeks of CT. da Silveira Rodrigues et al. [21] and Agner et al. [22] reported an improvement in aerobic performance evidenced by an increase in the distance covered in the 6-min walk test after 12 weeks of CT. Martins et al. [23] reported a significant increase in aerobic endurance of postmenopausal women at risk of diabetes after 12 weeks of CT, which was consistent with the results of this study. Previous studies have shown that a higher level of regular physical activity and cardiorespiratory fitness is associated with a reduced risk of coronary heart disease [24]. Low cardiorespiratory fitness is associated with increased metabolic disorders [25]. VO_2

Table 1. Exercise training program

Exercises	Resistance Exercise			
	Week 1-2	Week 3-4	Week 5-6	Week 7-8
Bench press Squat Seated row Lying leg curls Arm curl Standing fly	1 set×8-12 reps	2 sets×8-12 reps	3 sets×8-12 reps	4 sets×8-12 reps

Exercises	Aerobic Exercise			
	Week 1-2	Week 3-4	Week 5-6	Week 7-8
Running	10 sets×1 min×70-85% HR max	11 sets×1 min×70-85% HR max	12 sets×1 min×70-85% HR max	13 sets×1 min×70-85% HR max
Skipping rope	10 sets×1 min×40-45 jumps per min	11 sets×1 min×40-45 jumps per min	12 sets×1 min×40-45 jumps per min	13 sets×1 min×40-45 jumps per min

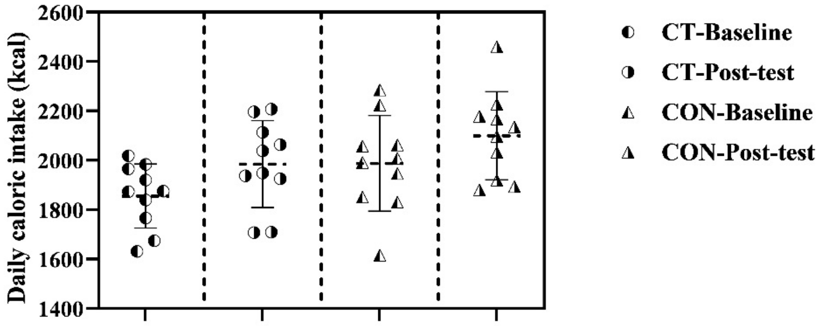

Figure 2. The daily caloric intake in overweight women with type 2 diabetes

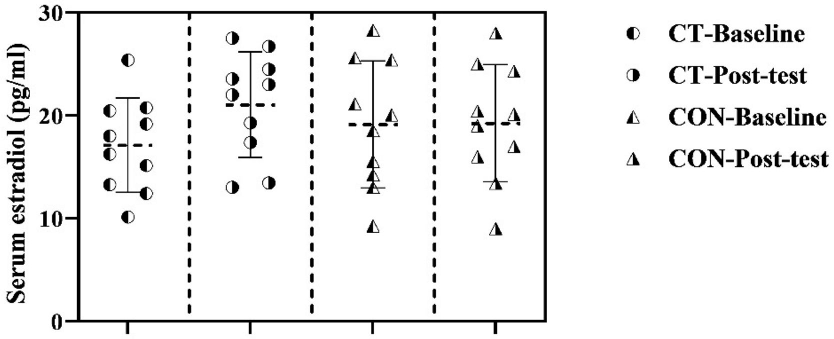

Figure 3. The serum estradiol level in overweight women with type 2 diabetes

max is influenced by central adaptations such as better cardiac function and local and general adaptations on the vasculature. Reducing peripheral blood pressure and blood viscosity due to increased plasma levels is an adaptation to exercise training [26]. One of the effective factors in improving VO_2 max is muscle adaptations, such as an increase in capillary density, level of oxygen delivery to muscle cells, mitochondria density, and mitochondrial enzymes [27].

In the present study, a significant increase in upper body (35.26%) and lower body (33.36%) muscle strength was observed in women with type 2 diabetes after 8 weeks of CT. In this regard, da Silveira Rodrigues et al. [21] reported a significant increase in muscle strength in patients with type 2 diabetes after 12 weeks of CT. Martins et al. [23] also reported a significant increase in muscle strength in postmenopausal women at risk of diabetes after 12 weeks of CT. Muscle weakness and lower limb atrophy may occur in patients with type 2 diabetes and increase their risk of falling. Almurdhi et al. [28] reported that the strength of the lower body muscles of patients with type 2 diabetes significantly decreased due to the decrease in muscle volume. These patients also experience a decrease in muscle strength due to the accumulation of fat in the muscles of the lower limbs, and this decrease in muscle strength and volume is related to peripheral neuropathy. The high level of inflammation and oxidative stress also contributes to muscle atrophy and a reduction in total muscle mass in these patients [29].

For this reason, functional capacity and movement abilities decrease in patients with type 2 diabetes [30]. In this context, the American College of Sports Medicine (ACSM) has approved increasing muscle strength and endurance to improve the health of type 2 diabetes patients [17]. The possible role of neuromuscular adaptations, muscle hypertrophy, and metabolic adaptations regarding the effect of exercise training on improving muscle strength and endurance can be mentioned [31].

In the present study, a significant increase (27.13%) in serum estradiol was observed in women with type 2 diabetes after 8 weeks of CT. Shabani [32] also reported a significant increase in serum estradiol levels in obese women with glucose tolerance disorder after 12 weeks of CT. Campbell et al. [33] did not report a significant difference in estradiol levels after 12 weeks of aerobic training, which was inconsistent with the results of the present study. The difference in the results is due to the difference in the training protocol or the difference in

Table 2. Effect of CT on physical fitness indicators in overweight women with type 2 diabetes

Variables	Group	Mean±SD			Statistical Result		
		Baseline	Post-test	Change (%)	F	P	$p\eta^2$
VO_2 max (mL/kg/min)	CT	24.15±1.58	36.74±2.94	52.32	282.670	<0.001	0.940
	CON	23.85±1.31	23.20±1.45	-2.74			
Arm curl (n)	CT	21.80±1.75	29.30±1.64	35.26	89.299	<0.001	0.832
	CON	22.00±2.54	21.60±2.17	-1.64			
30-s chair stand (n)	CT	17.30±2.41	23.00±3.53	33.36	53.821	<0.001	0.749
	CON	17.50±3.66	17.20±3.91	-1.64			
	CON	130.90±25.14	135.70±25.63	8.01			

CT: Concurrent training; CON: Control.

the age of the participants. All participants in Campbell et al.'s study had regular menstrual cycles [33], while the participants in the current study were near menopause and had lower estrogen levels. In old age, the estradiol level decreases due to insulin resistance. Estrogen level is one of the factors affecting vascular function in conditions of low estrogen level, such as menopause, endothelial function changes, and peripheral blood flow, including blood circulation in muscles, decreases, which may limit insulin delivery and increase insulin resistance [34]. One of the effective mechanisms in estrogen secretion is nitric oxide. Nitric oxide interacts with kisspeptin in the nervous system and increases sex hormones through the secretion of gonadotropin-releasing hormone [35].

The present study observed a significant decrease (23.40%) in the serum glucose level after 8 weeks of CT. Tan et al. [36] showed that 6 months of CT reduced serum glucose levels in older people with type 2 diabetes, which is in line with the results of the present study. Martins et al. [23] reported a significant reduction in serum glucose levels in postmenopausal women at risk of diabetes after 12 weeks of CT, consistent with our study's reduction in fasting glucose levels. The skeletal muscle consumes blood glucose as an energy source during exercise. The absorption process includes complex molecular signaling mechanisms that are different from the molecular mechanism related to the effect of insulin on glucose absorption. Membrane absorption of glucose, which is activated during physical activity, is a

Table 3. Effect of CT on cardiovascular risk factors in overweight women with type 2 diabetes

Variables	Group	Mean±SD			Statistical Result		
		Baseline	Post-test	Change (%)	F	P	$p\eta^2$
LDL/HDL ratio	CT	2.64±0.72	2.33±0.66	-9.25	3.471	0.079	0.162
	CON	3.18±0.79	3.30±0.88	5.11			
Serum triglyceride (mg/dL)	CT	198.40±94.84	145.90±2.21	-23.76	7.204	0.015	0.286
	CON	167.10±39.85	182.80±80.20	6.22			
Serum total cholesterol (mg/dL)	CT	185.02±28.39	173.80±30.23	-6.25	2.346	0.143	0.115
	CON	194.90±31.21	197.40±29.85	2.11			
FBS (mg/dL)	CT	129.80±17.80	98.10±13.55	-23.40	6.68	0.019	0.269
	CON	130.90±25.14	135.70±25.63	8.01			

Abbreviations: CT: Concurrent training; CON: Control; FBS: Fasting blood sugar; LDH: Low-density lipoprotein; HDL: High-density lipoprotein.

reason for emphasizing the value of physical activity in non-pharmacological treatment [8].

The present study observed a significant decrease (23.76%) in serum triglyceride levels. Also, there was no significant change in serum total cholesterol level and LDL/HDL ratio in women with type 2 diabetes. Banayi et al. [37] and Nasiri et al. 38] reported a significant decrease in serum triglyceride levels in women with diabetes after 8 weeks of CT, which was consistent with the results of the present study. These researchers also observed a significant decrease in serum total cholesterol levels, which is inconsistent with the results of the present study. In Nasiri et al.'s research [38], no significant difference was observed in LDL/HDL ratio in women with type 2 diabetes after 8 weeks of CT, which was consistent with the results of the present study. Rabiei et al. [39] also reported no significant difference in serum HDL and LDL levels in women with type 2 diabetes after 10 weeks of CT, which was consistent with the results of the present study. An increase in the concentration of LDL and, on the other hand, a decrease in HDL in patients with type 2 diabetes may increase the risk of cardiovascular disease. LDL accumulates more in the walls of blood vessels and causes disturbances in the activity of the heart and blood vessels. At the same time, HDL transports cholesterol from blood vessels to the liver, prevents fat accumulation in the blood vessels, and can reduce blood vessel clogging [40]. One of the determining factors of the effect of exercise training on lipid profile is body composition, so the reduction of body weight and fat mass is related to the decrease in total and LDL cholesterol levels and the increase in HDL levels [41]. Physical activity also plays an essential role in increasing the protein expression of adipose triglyceride lipase [42]. It is worth noting that as a result of exercise training, increasing the activity of lecithin cholesterol acyltransferase and decreasing the activity of plasmatic cholesterol ester transfer protein play essential roles in improving the lipid profile [41].

Every research has some limitations. In the current study, the lack of control of the level of motivation and mental states during the training and implementation of the tests; not blinding the subjects, personnel, and assessors; low sample size; non-random allocation of samples into two groups; and lack of measurement of long-term effects of CT program are among the limitations of the present research.

Conclusion

According to the results of the present study, 8 weeks of CT can improve physical fitness indicators and some cardiovascular risk factors in women with type 2 diabetes. Considering that the serum estradiol level increased in the present study, health-related institutions can use the benefits of CT to control blood glucose and prevent complications related to menopause and the elderly, such as osteoporosis.

Ethical Considerations

Compliance with ethical guidelines

The ethical permission for this work was received from the Research Ethics Committee of Hakim Sabzevari University (Code: IR.HSU.REC.1397.007).

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors contributions

Idea development and supervision: Amir Hossein Haghighi and Roya Askari; Data collection, data analysis and literature review: Fatemeh Azmand; Review and editing: Hadi Shahrabadi.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgements

The authors thank all the participants who helped them with this study.

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