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The effect of exercises on left ventricular systolic and diastolic heart function in sedentary women: Step-aerobic vs core exercises

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A B S T R A C T

The purpose of this study is to investigate the effect of 16 weeks step-aerobic exercises and core exercises on left ventricular structure and function with some physiological parameters in sedentary women.

Methods: To achieve the purpose of this study, a total of 45 volunteers including (step-aerobic group (SAG, n = 25), core exercise group (CEG, n = 20) were selected as participants. Two different exercises were applied for 4 days a week, throughout 16 weeks, within 60 minutes for each exercise with the intensity of heart rate (HR) 60-70 percent. The HR was measured using a heart rate monitor for each subject. The physical, biochemical and echocardiographic characteristics of the women were measured before and after the exercise.

Results: During the exercise periods, there were a meaningful decrease in the body weight, BMI, value of waist region and hip circumference of the women in both intervention groups as well as in the values of HR, DBP, SBP ($p < 0,05$). In addition, serum homocysteine (Hcy) and high-sensitivity C-reactive protein (Hs-CRP) levels decreased and the VO_{2max} and left ventricular diastolic end-diastolic dimension increased in both SAG and CEG ($p < 0.05$). The left ventricular diastolic functions of the SAG improved more than CEG. Left ventricular systolic ejection time and fractional shortening meaningfully improved in both SAG and CEG ($p < 0.01$).

Conclusion: 16 weeks of step-aerobic and core exercise showed significant changes of inflammatory and lipid markers with cardiac dimensions and had favorable effects on both left ventricular systolic function. Left ventricular diastolic function had more improved in SAG than the CEG.

1. Introduction

An increasing number of factors making life easier have brought have brought about an increased physical inactivity globally.[1] Sedentary life is one of the biggest public health problems in the 21st century.[2] There is strong evidence that physical weakness caused by inactivity decreases resistance to various diseases, increases risk of many diseases such as type 2 diabetes and obesity, and that coronary heart disease and hypertension are among the most important causes of death and disability.[3,4] The importance of regular physical activity is emphasized in order to maintain a healthy life and to have both preventive and healing effects for many diseases.[5,6] It is known that cardiovascular risk factors are greatly improved through the cardiovascular changes that occur with regular and long-term exercise.[3,7]

Many studies have shown that structural and functional changes in the left ventricle during exercise are greater than other parts of the heart.[8,9] Long-term exercises leading to morphological adaptation in the left ventricle may vary according to the type of sport being performed, its severity and extent. Regular endurance training can cause different changes in the structure and function of the heart and skeletal muscle.[10,11] Using conventional echocardiographic methods, both left ventricular (LV) diastolic and systolic functions have been shown to develop with training.[12–14]

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Many people who want to do sports practice in different exercises under the leadership of sports trainers. But what kind of cardiovascular exercise is more effective than it is important to clearly specify.

The present study determined whether step-aerobic or core exercises are more effective in left ventricular cardiac function development and reducing cardiovascular risk factors in middle-aged women.

2. Material and methods

2.1. Participants

Forty-five healthy sedentary women participated voluntarily in this study. We asked face to face all candidates self-reported. They did not attend regularly sports activities (more than one hour per week), before this study. All participants underwent health exams to ensure that they were not taking any medications and cigarettes or anti-pregnancy drugs and were free of any kind of heart disease, respiratory, metabolic or inflammatory disorders. All selected participants were randomly divided into two groups as step-aerobic group (SAG, $n = 25$, age 34.04 ± 3.74), core exercise group (CEG, $n = 20$, age 35.15 ± 6.25) years. The Clinical Research Ethics Committee in Medical Faculty of Ondokuz Mayis University approved the study (2012/141) in accordance with the policy statement of the Turkey Ministry of Health. The principles set out by the Declaration of Helsinki and national and local ethical guidelines for research were also followed. All participants completed a medical questionnaire and check up in the hospital then they were informed about the possible risks and discomfort involved before giving their written consent to participate.

3. Experimental procedure

3.1. Exercise intervention

The exercise program for two groups was undertaken 4 days of each week during 16 consecutive weeks. In both exercise group performed the exercise program in the gym under the leadership of sports trainers. Training intensity was calculated with Karvonen methods separately for each participant.[15] The target heart rate (THR) was controlled using a heartbeat monitor for each subject (Polar, made in Finland), and throughout the 16-week, exercise intensity was increased progressively from HR 60% to 70 % (between 1st and 4th week was HR 60%, between 5th and 8th week was HR 65% and 9th and 16th was HR 70%). Each exercise session was of 1h duration and consisted of warm-up exercises (10min), primary exercises (30-40min, basic movements step-aerobic) and cold-down (10 min). CE; warm-up exercises (10 min), primary exercises (30-40 min core exercises provide basically more strength for lower and upper extremities include 3 sets/day, 10 repetitions/set, 1–2min resting interval) and cold-down (10 min).[16,17]

3.2. Procedure and measurement

Height was measured to the nearest 0.1cm on a stadiometer when the participants were shoeless. Body weight of subjects in bare feet, t-shirts and tights was measured by the weighing instrument in kilograms ±0.01 kg. Body height of participants in bare feet was measured by the ruler in centimeters ±0.01 cm. Body mass index (BMI) was calculated as weight/height2 (kg/m2). The fat mass to determine Bodystat 1500 MDD equipment was used. The participants were asked to breathe out for measurement of their waist circumference (WC), which was measured to the nearest 0.1cm at the iliac crest. When viewed from the side, hip circumference (HC) was evaluated at the level of the maximum extension of the thigh, and waist-hip ratio (WHR) equals the waist circumference (WC) divided by the hip circumference (HC); WC (cm)/height (m).

3.2.1. Resting heart rate

12-lead electrocardiogram, and blood pressure (BP) were recorded in the sitting position. The participants were told to sit upright in a straight backed chair. Both feet were placed flat on the floor and the right arm was resting on a table with the elbow in a flexed position. BP at rest was obtained from the right arm by auscultation using a mercury sphygmomanometer and the resting heart rate (HR) was recorded from a 12-lead electrocardiogram with the subject sitting in an armchair just before the upright exercise test.

3.2.2. Maximal oxygen uptake

Maximal oxygen uptake (VO_{2max}) was determined by 20 m shuttle run test. For this aim, Powertimer PC 1.9.5 Version Newest device was used. This consisted of shuttle running between two met alters placed 20m apart at increasing fast speeds. Two photocells has been placed on the starting and ending at the 20 meters running distance.

3.2.3. Blood sample analyses

Blood was drawn from the deep arm vein in the morning after overnight fasting at the pre and post 16 weeks. Total cholesterol (TC), High density lipoprotein-cholesterol (HDL-C), triglyceride (TG) was assessed by the enzymatic colorimetric test (Roche diagnostics Moduler P 800).

Low density lipoprotein-cholesterol (LDL-C) was calculated by the formula TC2 (HDL-C1TG/5).

Serum Homocysteine (Hcy) and high-sensitivity C-reactive protein (Hs-CRP) were measured using immunodiffusion (ELİZA Perkın Elmer Vıctor).

3.3. Echocardiography

The participants underwent a standard echocardiographic examination M-mode, two-dimensional echocardiographic and pulse Doppler studies were performed using (Vivid 7 scanner with a 2.5 MHz transducer (GE Vingmed Ultrasound, Horten, Norway) with a 2.5 MHz transducer. Examinations were performed by one experienced cardiologists, who is blinded to the group intervention, with subjects resting in the left lateral supine position.

Two dimensional echocardiography was performed at the time of the baseline assessment and at 16 weeks. Echocardiograms were performed by experienced cardiologists and repeated by the same technician within each center wherever possible, with care taken to obtain similar serial images. Images were videotaped at the end of the expiration phase of normal respiration. A standard protocol was used based on apical four and two-chamber views according to the recommendations of the American Society of Echocardiography.[18,19] The following variables were measured or derived: LV end-diastolic dimension (LVDD), end-systolic dimension (LVSD), interventricular septum thickness (IVS), left ventricular posterior Wall (LVPW), MDT = mitral deceleration time, left ventricular ejection fraction (LVEF), left ventricular Fractional shortening (LVFS).

(LVEF) was calculated as quotient LVEF = (LVEDV−LVESV)/LVEDV × 100

(LVFS) was calculated as the quotient LVFS = (LVEDD−LVESD)/LVEDD × 100

Pulsed Doppler mitral flow was recorded in an apical two dimensional four-chamber view with the sample volume placed at the tips of the mitral valve leaflets opened during diastole. Early peak (E), atrial peak (A) LV filling velocities and the E/A ratio were used as indexes of global diastolic function.[20]

3.4. Statistical analysis

All statistical data obtained from the study was calculated with licensed.

SPSS 19.0 packet program. Arithmetic means and standard deviation were calculated with this program. Test of normality for the data's were made by Shopiro-Wilcoxon test. And then parametric tests applied. The evaluation inside the group was made by Paired Samples-t test, and evaluations between-group differences in baseline values and intervention induced changes were tested by analyses of variance independent-t test. Statistical significance were accepted as and $p < 0.05$, $p < 0.01$.

4. Results

In intragroup comparison before and after 16 weeks of exercise (Table 3), significant decrease in weight, BMI, fat mass, waist, hip, SBP and HR values ($p < 0.01$) and DBP value ($p < 0.05$) of SAG and CEG was detected. VO_{2max} values also showed significant increases in both groups ($p < 0.01$). In intergroup comparisons (Table 3); The CEG program was found to be more effective in improving hip value than SAG ($p < 0.05$).

Serum lipids and inflammatory markers after 16 weeks of exercise (Table 4); significant decrease in TC, Hcy and Hs-CRP values ($p < 0.05$) of SAG and CEG was detected. LDL-C values also showed significant decrease in SAG ($P < 0.01$) and CEG ($p < 0.05$).

When looked at echocardiography results after 16 weeks of exercise (Table 5); Left ventricular cardiac structural parameters of SAG improved better than CEG ($p < 0.05$). Significant improvement in left ventricular diastolic function parameters was observed only in Mitral A ($p < 0.05$) and Mitral E/A ($p < 0.01$). While there was a significant improvement in EF and FS in left ventricular systolic function of both exercise groups ($p < 0.05$). When we comparison between groups left ventricular posterior wall parameter of CEG improved better than CEG ($p < 0.05$).

5. Discussion

5.1. Physical and physiological parameters

In this study, middle-aged sedentary women were given a 16-week aerobic-step and core exercise program, and the effects of exercise programs applied to prevent left ventricular diastolic and systolic functions and cardiovascular risk diseases as well as changes in physical, anthropometric and physiological parameters of both exercise groups were examined.

In our study, both groups of exercise caused significant changes in body mass, BMI, fat mass, waist and hip parameters positively, and that regular aerobic and strength exercises were effective on physical and anthropometric parameters positively.[3,21–23] Comparing the two groups, it can be concluded that CEG causes more decrease around the hip than SAG because core exercises mainly provide more force production to the upper and lower limbs, and mainly involve regional exercises.[24,25] The most important risk factor for cardiovascular morbidity and mortality is hypertension[26] and it is also known that increased resting heart rate is an independent risk factor associated with cardiovascular morbidity and mortality.[27] In addition, increased heart rate may also increase atherosclerosis, cardiac ischemia, cardiac hypertrophy and heart failure.[28,29] In the Framingham heart study, patients with high-normal blood pressure (systolic blood pressure 130-139 mmHg, diastolic blood pressure 85-89 mmHg, or both) were twice as likely to have a cardiovascular disease risk compared to those at low levels.[30,31] In this study, SBP decreased from 127 ± 6 to 122.7 ± 5.9 mmHg, DBP decreased from 75.8 ± 4.6 to 73.2 ± 5.2 mmHg in SAG, and SBP decreased from 130 ± 9 to 126.4 ± 7.6 mmHg, DBP decreased from 78 ± 6.6 to 73.7 ± 4.3 mmHg in CEG. It was also observed that systolic and diastolic blood pressures of SAG and CEG were closed to cardiovascular disease risk before exercise, but at the end of the study there was a positive improvement indicating that subjects in both exercise groups were away from the risk of cardiovascular disease. It can be argued that the regular exercise of aerobic and strength exercises causes positive developments in systolic and diastolic blood pressures.[3,32] Significant reductions in HR of SAG and CEG were observed in our study. It can be thought that aerobic and resistance exercises cause significant reductions in heart rate with regular training in sedentary middle-aged women[33] and the contraction strength of the heart is caused by increases in the pulse volume.[34,35]

Table 2
Anthropometric data (mean ± SD).

	SAG (n = 25)	CEG (n = 20)
Age (years)	34 ± 3.7	35.1 ± 6.2
Height (cm)	159.3 ± 5.8	159 ± 6.1
Weight (kg)	74.2 ± 8.7	74.9 ± 8.1
BMI (kg/m^2)	29.3 ± 3.5	29.6 ± 2.2

Table 1
Core exercises program.[17]

Exercises pProgram	Intensity	Core exercise	Frequency
Warm –up (10 min)	RPE, 7–9		
Main exercise (35-40 min)	60%-70% 3 sets/10 repetitions/set, (1–2min resting interval)	Hip lifts with knee	4 Times/wk
		Crunches	
		Side crunch	
		Double crunch	
		Reverse crunch	
		Legs straight up crunches	
		Side-lying crunch	
		Half-up twists	
		Bicycles	
		Push-ups on knees	
		Plank leg lifts	
		Superman — opposite arm and leg extension	
		Squats	
		Side lunge, left and right	
Cooldown (10 min)	RPE, 7–9	Stretching	

Table 3
The comparison of physical and physiological parameters between baseline and after 16 weeks.

Variables	Step-aerobic group (SAG)		Core exercise group (CEG)	
	Pre (0 wks.)	Post (16 wks.)	Pre (0 wks.)	Post (16 wks.)
Weight (kg)	74.2 ± 8.7	69.5 ± 8.7**	74.9 ± 8.1	70.6 ± 7.8**
BMI (kg/m^2)	29.3 ± 3.5	27.5 ± 3.6**	29.6 ± 2.2	27.9 ± 2.3**
Fat Mass (kg)	29.5 ± 7.8	24.8 ± 6.8**	30.2 ± 5.1	24.9 ± 4.8**
Waist (cm)	93.8 ± 11.8	88.1 ± 9.8**	94 ± 6.8	87.1 ± 6.4**
Hip (cm)	113.6 ± 7.6	108.3 ± 8.7**	113 ± 5.7	106.2 ± 5.9**
WHR (cm)	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.8 ± 0.1
SBP (mmHg)	127 ± 6	122.7 ± 5.9**	130.1 ± 9	126.4 ± 7.6**
DBP (mmHg)	75.8 ± 4.6	73.2 ± 5.2*	78 ± 6.6	73.7 ± 4.3*
Rest HR (beats/min)	84 ± 10.9	76.4 ± 8**	85.6 ± 10.6	78.2 ± 7.6**
VO_{2max} (ml/kg/min)	25.7 ± 1.3	33.3 ± 3.8**	25.1 ± 1.7	31.2 ± 4.1**

Values are means ± SD. *P < 0.05: The mean difference is significant at the 0.05 level (paired t-test); **P < 0.01: The mean difference is significant at the 0.01 level (paired t-test).
#p < 0.05: The mean difference is significant at the 0.05 level (Independent-t test).
Abbreviation: BMI: body mass index, WHR: waist/hip ratio, SBP:systolic blood pressure, DBP:diastolic blood pressure, HR: hearth rate, VO_{2max}: maximal oxygen uptake.

Table 4
The comparison of serum lipids and inflammatory markers between baseline and after 16 weeks.

Variables	Step-aerobic group (SAG)		Core exercise group (CEG)	
	Pre (0 wks.)	Post (16 wks.)	Pre (0 wks.)	Post (16 wks.)
TC (mg/dl)	181.2 ± 35.8	169.0 ± 25*	178.4 ± 38.9	167.9 ± 34.8*
TG (mg/dl)	112.5 ± 61.2	109.3 ± 43.3	102.0 ± 55.1	91.1 ± 27.5
HDL-C (mg/dl)	52.9 ± 10.4	52.4 ± 9.1	58.4 ± 12.9	58.5 ± 10.2
LDL-C (mg/dl)	105.2 ± 30.4	94.3 ± 22.3**	99.0 ± 33.7	90.5 ± 31.4*
Hcy (μmol/L)	10.1 ± 6.1	7.5 ± 3.9*	10.2 ± 4.4	8.2 ± 2.8*
Hs CRP (mg/L)	1.5 ± 1.5	0.6 ± 1.0*	1.2 ± 0.9	0.4 ± 0.9*

Values are means ± SD. *P < 0.05: The mean difference is significant at the 0.05 level (paired t-test); **P < 0.01: The mean difference is significant at the 0.01 level paired (t-test); #p < 0.05: The mean difference is significant at the 0.05 level (Independent-t test; X±SD: mean ± standard deviation.
Abbreviation: TC: Total cholesterol; TG: Triglyceride; HDL-C: high density lipoprotein- cholesterol; LDL-C:Low density lipoprotein; Hcy: Homocysteine; Hs-CRP: high-sensitivity C-reactive protein.

Table 5
The comparison of left ventricular (LV) function between baseline and 16 weeks.

Variables	Step-aerobic group (SAG)		Core exercise group (CEG)	
	Pre (0 wks.)	Post (16 wks.)	Pre (0 wks.)	Post (16 wks.)
LVEDD (mm)	46.2 ± 2.1	47.1 ± 2.8*	45.0 ± 2.7	46.5 ± 2.8*
LVESD (mm)	28.3 ± 2.3	28.3 ± 2.0	27.5 ± 2.4	27.3 ± 1.9
IVS (mm)	10.6 ± 0.6	11.0 ± 0.6*	10.5 ± 0.7	10.6 ± 0.6
LVPW (mm)	10.2 ± 0.8	11.0 ± 0.6**	10.1 ± 0.9	10.4 ± 0.7#
Mitral E (m/s)	0.78 ± 0.1	0.82 ± 0.1	0.80 ± 0.2	0.85 ± 0.1
Mitral A (m/s)	0.66 ± 0.1	0.57 ± 0.1*	0.62 ± 0.1	0.63 ± 0.1
Mitral E/A	1.19 ± 0.2	1.44 ± 0.2**	1.34 ± 0.4	1.38 ± 0.3
LVEF (%)	68.4 ± 3.7	70.4 ± 3.3*	68.5 ± 4.7	70.5 ± 3.4*
LVFS (%)	39.0 ± 3.1	40.2 ± 3.2*	38.1 ± 3.7	40.1 ± 3.2*

Values are means ± SD. *P < 0.05: The mean difference is significant at the 0.05 level (paired t-test); **P < 0.01: The mean difference is significant at the 0.01 level (paired t-test); #p < 0.05: The mean difference is significant at the 0.05 level (Independent-t test; X±SD: mean ± standard deviation.
Abbreviation: LVEDD: left ventricular end-diastolic dimension, LVESD: left ventricular end-systolic dimension, IVS: interventricular septum thickness, LVPW: Left ventricular posterior wall, E: peak early diastolic mitral flow velocity, A: peak late diastolic mitral flow velocity, LVEF: left ventricular ejection fraction, LVFS: left ventricular Fractional shortening (Tables 1 and 2).

VO_{2max} is accepted as a demonstration of cardiovascular health and cardiopulmonary fitness.[36] One of the aims of our study was to increase women's VO_{2max} by applying step-aerobic and core exercise programs at 60-70%[37–39] in addition, improving left ventricular cardiac parameters.[40,41] At the end of the study, there was a positive increase in VO_{2max} in SAG and CEG[42] and resulting in positive improvements in some cardiac parameters of the left ventricle. For this reason, we can say that regular exercises on women in both exercise groups benefit cardiorespiratory fitness and primary and secondary protection of cardiovascular diseases.[43]

Lipid and lipoprotein abnormalities play a major role in the development and progression of coronary artery disease.[44] Benefits include improved serum lipid profiles, blood pressure and inflammatory markers as well as reduced risk of stroke, acute coronary syndrome and overall cardiovascular mortality[45]

Several studies have shown that exercise can cause improving effect on serum HDL-C, LDL-C and TG[46,47] while some other studies didn't found any significant differences after exercises.[48,49] We found significant decrease in serum TC and LDL-C levels in SAG and CEG after 16-week exercise period. Our study showed that both exercise interventions have lowered serum bad cholesterol profile, which are related to atherosclerosis. On the other hand, HDL-C is called "good" cholesterol. Its level that are below 50 mg/dL for women indicate an increased risk of atherosclerotic cardiac disease. We didn't find any significant change in HDL-C levels after exercise period. But serum HDL-C levels in both exercise groups were within normal limits (52.9 ± 10.4 for SAG and 58.4 ± 12.9 for CEG) before the exercise period in our study. We can say that exercise intervention can not affect HDL-C levels in women with normal HDL-C values. These finding also suggest that women with lower levels of HDL-C are more likely to benefit from exercise training.

Serum Hcy and Hs-CRP levels are well known risk factor for atherosclerosis and related cardiovascular diseases.[50] The cut-off points of low risk (<1.0 mg/L), average risk (1.0 to 3.0 mg/L), and high risk (<3.0 mg/L) correspond approximately of hs-CRP tertile in the adult population.[51] Our study have significantly improved serum Hs-CRP level in SAG of 1.5 ± 1.5 to 0.6 ± 1.0 and CEG of 1.2 ± 0.9 to 0.4 ± 0.9 after 16-week exercise period and also Hcy levels significantly decreased in both groups. These findings suggest that both of the aerobic and core exercise interventions have efficiently reduced the serum inflammatory markers even at low concentrations.

5.2. Left ventricular function

The effects of regular exercise on the heart have been known for many years.[4] It is generally accepted that intensive and long-term physical training stimulates heart-balanced hypertrophy with increased cavity dimensions of right and left ventricles with increased left ventricular wall thickness.[14,52] In our study, as a result of SAG and CEG 16-week programs, the improvement in left ventricular cardiac parameters in both groups may be attributed to the ability of long-term aerobic and force exercises to increase the left ventricular dimension and ventricular septum to thicken the posterior wall, as well as to alter eccentric left ventricular hypertrophy.[53,54] Significant increases were observed in the LVEDD, IVS and LVPW values of SAG, while the LVEDD value of CEG was significantly increased, but the IVS and LVPW values were slightly improved. In contrast to SAG improved in left ventricular cardiac structural functions than CEG, no significant improvement was found in the LVESD values of both groups. This is because of that some studies do not show significant changes in heart size with exercise, but some may cause significant increases.[55,56] In addition, these changes may show some changes depending on the intensity and duration of the exercise.[57]

Regular exercise increases venous return to heart and thus increases cardiac output (CO).[58] This index represents the ejection fraction (EF), which is the systolic capacity of the left ventricle. Left ventricular EF is assessed using the total amount of blood entering the left ventricle and the amount of blood remaining after a beat.[4] Briefly, EF shows the state of contraction of the heart.[59] EF and FS values of both groups increased significantly in our study. This can be attributed to the fact that in both groups, after long-term exercise, aerobic capacity development and VO_{2max} value were increased, and both groups were well adapted to the exercises applied, resulting in improved left ventricular systolic function.[57]

Various studies such as durability, combined dynamics and strength sports have shown that they improve diastolic performance indices.[60–62] As a result of our regular 16-week exercises, it was found that there was increase in E/A ratio of only SAG,[14,63] and Mitral A value was decreased.[14] For this reason, we can say that aerobic exercises are more effective in improving the diastolic function of the heart in sedentary women.

6. Conclusion

In this study, regular step-aerobics and core exercises have been shown to reduce the risk of cardiovascular disease with the development of VO_{2max} in sedentary women and a significant improvement in systolic and diastolic blood pressures as well as reduction of LDL-C with inflammatory markers such as hs-CRP and Hcy. In addition, improvement in left ventricular cardiac parameters and systolic function was observed in both exercise types. Step-aerobic exercise can be said to be a more effective exercise in improving left ventricular diastolic function. One limitation of our study is that we did not perform nutritional restriction in our study groups and focused on the effect of only exercise intervention in sedentary women. Further studies are needed to evaluate the combined effect of both exercise and diet on atherosclerotic risk factors.

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