THE EFFECT OF ENDURANCE, RESISTANCE AND CONCURRENT TRAINING ON THE HEART STRUCTURE OF FEMALE STUDENTS

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ABSTRACT: The aim of this study was to compare the effect of endurance, resistance and concurrent training on the heart structure. Thirty-nine untrained female students (mean age 24±2.58 yrs) were randomly divided into four groups: Control (C; n=9), Endurance (E; n=10), Strength (S; n=10) and Concurrent (SE; n=10).E group training consisted of running at 65% of maximum heart rate (MHR) for 16 min per training unit during the first week, reaching 80% of MHR for 30 min during the 8th week. S group training consisted of performing four leg presses, bench presses, pull down curls, and leg curls. During the first week, the training was performed at 50% of one repetition maximum (1RM) in 2 sets with 10 repetitions. The intensity of training increased to 80% 1RM in 3 sets and 6 repetitions during the 8th week. The SE training included the sum of the training performed by the E and S training groups. Left ventricular end diastolic and systolic diameters, post-wall thickness, left ventricular mass and mass index and septum wall thickness were measured by m-mode and 2-D echocardiography as the structural parameters. The end diastolic diameter in E and SE groups, the ventricular end systolic diameter, left ventricular mass and mass index of the SE group after the training increased ($P \leq 0.05$). In comparing the groups, only the increase of the end diastolic diameter in the SE group was significant ($P \leq 0.05$). The 8 weeks of concurrent training compared with endurance or resistance training alone resulted in a significant increase in left ventricular end diastolic diameter. However, no significant differences were found for any other measured variables.

KEY WORDS: **left ventricular end diastolic diameter, left ventricular end systolic diameter, septum wall thickness, left ventricular mass index**

INTRODUCTION

Physical training causes structural and functional changes in the heart, particularly in the left ventricle [6]. These changes constitute the cardiac adaptability phenomenon following the physiological, in contrast with the pathological changes brought about by hypertension and aortic stenosis [15,16]. In the case of disease, the heart confronts elevated pressures, but physiologically such pressures affect the heart only during physical training. The impact of physical training on cardiac structure and function depends on the type, intensity and duration of training, as well as previous physical fitness, genetics and gender [5]. Continuous, long-term physical activities exert an overload on cardiac muscles, resulting in an exogenous hypertrophic pattern with normal ventricular walls and increased ventricular (especially left ventricular) volume [9,10,13,23]. In addition, these individuals have greater diastolic filling volume, left ventricle diameter and mass, ventricular capacity, and stronger myocardial contraction, as explained by the Frank-Starling law [7]. Resistance training leads to an increase in the peripheral vascular resistance and blood pressure during training, and consequently pressure overload of the heart, resulting in concentric hypertrophy of the left ventricle in the long run [2,3]. In this type of structural adaptation, the septum and the posterior left ventricular wall thicken, whereas the ventricular volume remains intact [12]. However, training multiple energy systems and performing various types of training such as endurance and strength training simultaneously, referred to as concurrent training, has important implications for the physiological adaptations of such training programmes. Concurrent training produces greater cardiac hypertrophy and ventricular wall thickness than endurance and resistance training alone [14,21,22]. Two studies demonstrated similar cardiac structural changes with concurrent and endurance training [1,4].

In another study, concurrent training did not cause significant structural changes in the heart in comparison to resistance and endurance training [20]. Sagiv [18] compared the echocardiographic cardiac structure of endurance runners and weight lifters with non-athletes and concluded that the interventricular septum is significantly thicker in athletes than non-athletes.

Pluim et al. [17] studied the hearts of 1451 athletes and concluded that the absolute average thickness of the posterior wall of the left ventricle and the interventricular septum in the control group is significantly less than in the resistance, endurance, or concurrent training groups. Also, the thickness of the left ventricle, the interventricular septum, and the posterior wall is greatest in power athletes. Sanjay [19] studied the cardiac structure of athletes practising concurrent exercises for judo, endurance swimming, rowing, and cycling; the afterload and thickness of the left ventricle wall were greater in judo, without significant changes in the left ventricle volume. The concurrent group had the greatest left ventricular mass index. Urhausen et al. [22] assessed the hearts of female endurance runners and rowers by echocardiography and reported that left ventricular mass, thickness of the posterior left ventricular wall, and hypertrophy index were significantly greater in rowers than in the control group, but similar to the endurance runners.

Considering the limitations in studying female cardiac adaptations to endurance and resistance training and also the rarity of studies dealing with concurrent training, the present study was designed to assess the effects of endurance, resistance, and concurrent training on female cardiac structure.

MATERIALS AND METHODS

Subjects. Thirty-nine non-athletic female students were chosen as subjects of the study. The study protocol was approved by the research ethics committee of Tarbiat Modarres University and each participant gave informed consent before enrolment. The inclusion criteria were cardiovascular and general health, and lack of previous regular physical training. The criterion for cardiovascular health was the data obtained from the questionnaire devised by the researcher. Subsequently, the subjects' ECGs were studied to confirm their cardiac health. Before the initiation of the study, the subjects were informed of the process and filled out the medical sport questionnaire and the consent form. Then they were randomly assigned to 3 training groups as the endurance, resistance, concurrent and control group. The reason for using these two groups (endurance and resistance) was to enable us to separate the pure effects of resistance and endurance training on the structure of the heart during data interpretation.

Training programmes

The endurance training consisted of jogging with the intensity of 65% of maximum heart rate (MHR) on a treadmill for 16 min per training unit during the first week, reaching 80% of MHR for 30 min during the 8th week [8].

The resistance training consisted of leg press, bench press, pull down curls, and leg curls. During the first week, the exercises were performed with 50% of one repetition maximum (1RM) in 2 sets with 10 repetitions and a recovery period of 1-2 min. The intensity of the workout increased to 80% of 1RM in 3 sets with 6 repetitions during the 8th week. At the end of the first 4 weeks, the 1RM was measured and the training programme for the second 4 weeks was devised based on the new 1RM [8].

The training for the concurrent group was the sum of the programmes for the endurance and the resistance groups in each session. The resistance training was performed before the endurance to avoid premature fatigue caused by endurance training [8]. All of the training programmes were performed 3 days per week for 8 weeks. The subjects warmed up for 10 min before starting the main programme, and cooled down for 10 min after the main programme. All the training sessions were supervised by the researcher.

Measuring the cardiac structural variables

The structural variables were measured by echography before and after training, using 1 and 2 dimensional methods. These variables were measured in the echocardiography ward at Tehran Rasul-e-Akram Hospital by a cardiologist, using an HP Sono 1500 device made in the United States.

Before echocardiography, height, weight, and body fat percent (measuring the subcutaneous fat at triceps, suprailiac, and thigh, using the Jackson and Pollack formula) were measured [11]. The subjects were not significantly different in terms of weight, body surface area (BSA), or body mass index (BMI) before the study. Subsequently, the subjects were asked to assume the left lateral decubitus position and the optimal images of heart chambers were chosen to measure left ventricular end diastolic diameter (LVEDD), left ventricular end systolic diameter (LVESD), septum wall thickness (SWT) and posterior wall thickness (PWT). Using the 2-dimensional technique, the left ventricular mass (LVM) was measured and the left ventricular mass index (LVMI) was calculated using weight and height of the subject.

Statistical method

Descriptive statistics, one way ANOVA and Scheffe' tests were used for statistical analyses, and p equal to or less than 0.05 was considered as the significance level.

TABLE 1. GENERAL CHARACTERISTICS OF THE SUBJECTS

Groups	Number	Age (yr)	Height (cm)	Body mass (kg)	Body fat percent (%)	BMI ($kg \cdot m^{-2}$)	BSA (m^2)
Control	9	25.2 ± 2.5	161 ± 8.3	51.8 ± 4.4	17.4 ± 2.7	21.0 ± 1.2	1.51 ± 0.10
Endurance	10	25.3 ± 3.6	160 ± 9.9	59.5 ± 11.2	19.0 ± 4.4	23.2 ± 1.8	1.60 ± 0.14
Resistance	10	23.4 ± 1.6	162 ± 7.4	59.8 ± 14.6	18.4 ± 5.0	22.8 ± 1.9	1.63 ± 0.16
Concurrent	10	23.2 ± 2.5	160 ± 10.5	57.9 ± 12.8	18.0 ± 4.3	22.3 ± 1.7	1.60 ± 0.16

TABLE 2. ABSOLUTE VALUES OF CARDIAC STRUCTURAL FEATURES IN THE RESISTANCE, ENDURANCE, CONCURRENT, AND CONTROL GROUPS

	Variables		Endurance	Resistance	Concurrent	Control
Before training	LVEDD	(mm)	43.2 ± 3.2	43.6 ± 3.2	41.2 ± 5.1	41.9 ± 2.3
	LVESD	(mm)	25.9 ± 3.0	26.2 ± 2.7	25.3 ± 2.0	25.5 ± 1.9
	SWT	(mm)	7.9 ± 3.8	7.0 ± 0.3	6.9 ± 0.4	6.7 ± 1.1
	PWT	(mm)	6.0 ± 0.8	5.8 ± 0.8	6.0 ± 1.0	5.3 ± 1.0
	LVM	(g)	96.3 ± 19.3	88.5 ± 18.0	79.9 ± 23.2	70.8 ± 11.8
	LVMI	$(g \cdot m^{-2})$	60.2 ± 10.6	53.8 ± 8.4	48.9 ± 9.5	46.4 ± 6.30
After training	LVEDD	(mm)	44.4 ± 3.1*	44.4 ± 4.0	45.4 ± 5.7*	41.0 ± 2.2
	LVESD	(mm)	26.7 ± 3.1	26.4 ± 2.3	27.0 ± 3.4*	24.5 ± 2.0
	SWT	(mm)	7.9 ± 1.8	6.9 ± 0.6	6.8 ± 0.6	6.7 ± 1.9
	PWT	(mm)	5.8 ± 1.2	6.2 ± 1.5	6.4 ± 1.4	5.4 ± 1.1
	LVM	(g)	98.8 ± 36.5	93.1 ± 23.0	91.5 ± 23.7*	70.7 ± 11.8
	LVMI	$(g \cdot m^{-2})$	61.8 ± 20.4	56.0 ± 9.1	56.3 ± 10.2*	46.0 ± 6.7

*significant compared with before training (P≤0.05)

RESULTS

General features and demographic characteristics of the participants are summarized in Table 1. Absolute values of cardiac structural features of the participants are summarized in Table 2.The left ventricular end diastolic diameter of the endurance and concurrent groups increased significantly after training (P≤0.05). The highest increase pertained to the concurrent group. The increase in end systolic diameter, left ventricular mass, and mass index were significant only in the concurrent group (P≤0.05).

The change in left ventricular end diastolic diameter in the concurrent group was significantly different from the other groups (P≤0.05). No significant difference was observed in end systolic diameter, posterior wall thickness, septum wall thickness, left ventricular mass or mass index among the groups (P>0.05). A sample echocardiogram of subjects at end diastole at rest, in the Control (C), Endurance (E), Strength (S) and Concurrent (SE) groups, is shown in Figure 1.

DISCUSSION

In the present study, the left ventricular end diastolic diameter increased significantly following endurance and concurrent training, maximally in the concurrent group. Endurance activities bring about a volume overload which increases the initial diastolic filling at rest and exercise. The elevated end diastolic diameter in the concurrent group may be due to the combination of endurance and resistance training which adds pressure overload to volume overload, as a result of the duration and intensity of training. Other researchers including Urhausen et al. [22] and Pluim et al. [17] did not observe significant differences in end diastolic diameter between athletic and control groups.

These contradictory results are probably due to differences in training duration, methods, subjects' experience, ethnicity, gender, and also the techniques for measuring the left ventricular end diastolic diameter. In our study, the left ventricular end systolic diameter, left ventricular mass, and mass index increased significantly only in

C
E
S
SE

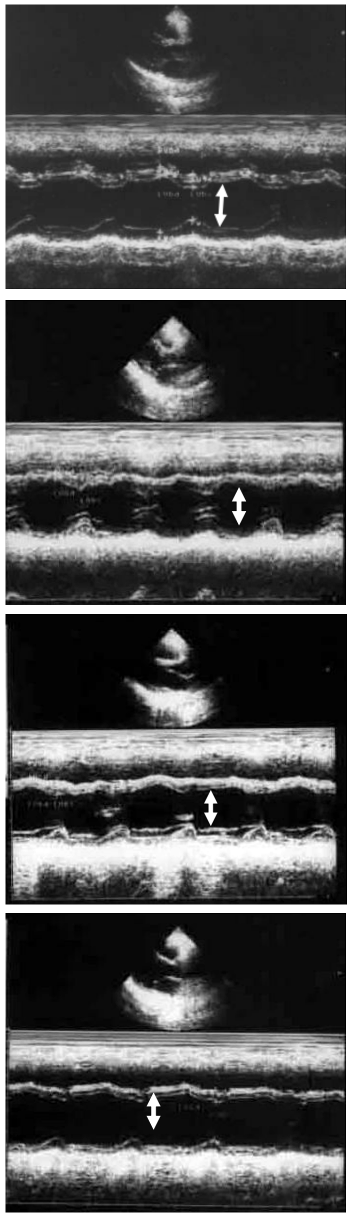

FIG. 1. SAMPLE ECHOCARDIOGRAM OF SUBJECTS' LEFT VENTRICULAR END DIASTOLIC DIAMETER AT REST, IN THE CONTROL (C), ENDURANCE (E), STRENGTH (S) AND CONCURRENT (SE) GROUPS.
(ARROW (↕) SHOWS THE LEFT VENTRICULAR END DIASTOLIC DIAMETER, LVEDD)

the concurrent group, which may be due to the nature of concurrent training, that is, exertion of both overload patterns.

A non-significant increase in structural variables was observed in endurance and resistance groups. The changes in left ventricular end systolic diameter, mass, and mass index were not significant among groups. The short duration of the training programme impeded the development of obvious structural modifications. Sanjay [19], Missault et al. [14] and Alijani [1] did not report significant structural changes in the heart. On the other hand, Wernstedt et al. [24], Di Bello et al. [4] and Somauroo et al. [21] observed significant differences between athletes and control groups. These differences may be due to longer duration of training, type of training, history of training in subjects, different statistical populations, and the psychological stress level of subjects.

In this study, the thickness of the posterior wall and the interventricular septum were not different in groups and among them. An 8-week training programme with the mentioned intensities does not provide sufficient stimuli for such modification of cardiac structure. One reason for the increase in the end diastolic diameter in concurrent and endurance groups and the end systolic diameter in the concurrent group may be that the ventricular chambers are enlarged because of the lack of wall thickening. D'Andrea et al. [3], Somauroo et al. [21], Missault et al. [14] Sagiv [18], Urhausen et al. [22] and Alijani [1] reported a significant difference in the thickness of cardiac walls between athletes and control groups. The intensity and duration of training, ethnicity, age, and gender explain these inconsistencies. Since the researchers used athletes of different sports in their studies, and performed some post-training sessions emphasizing the permanence of exercise effects, contradictory results and sometimes various changes of factors may occur during the course of study.

CONCLUSIONS

The results of this study indicate that the athlete's heart (particularly the left ventricle) enlarges following training. It seems that this enlargement not only hinders cardiac function, but also enhances it. However, in our study, the thickness of the posterior wall and the interventricular septum were not significantly different within or between groups after 8 weeks of training.

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