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Echocardiographic Evaluation of the Effects of High-Intensity Interval Training on Cardiac Morphology and Function

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Abstract

Background: High-intensity interval training (HIIT) is a time-efficient alternative to traditional prolonged training. In contrast to ample evidence describing the effects of prolonged training, there are few data describing cardiovascular adaptations arising from HIIT interventions.
Objectives: The present study aimed to evaluate the effects of HIIT on heart morphology and function in untrained male subjects.
Patients and Methods: Twenty-two young men (age = 23.34 $\pm$ 2.56 years, weight = 72.47 $\pm$ 12.01 kg, and height = 174.10 $\pm$ 5.75 cm) were recruited and randomly assigned into control (n = 10) and HIIT (n = 12) groups. Echocardiography was used to evaluate left ventricular mass (LVM), end-systolic volume (ESV), end-diastolic volume (EDV), interventricular septal wall thickness (IVSWT), stroke volume, and ejection fraction (EF). Also, the Bruce treadmill test was employed to estimate VO_{2max}.
Results: The HIIT subjects showed a significant increase in EDV (P = 0.001), LVM (P = 0.002), stroke volume (P = 0.003), and EF (P = 0.001). However, there was no change in ESV due to HIIT (P = 0.916). Additionally, following HIIT, IVSWT (P = 0.227), despite exhibiting a slight increase, was not significantly different from pre-training levels.
Conclusions: HIIT in previously untrained subjects led to a significant change in left ventricle (LV) morphology, correlating with improvement in aerobic power (VO_{2max}). Cardiac remodeling was characterized by an increased EDV and a similar increase in LVM.

Keywords: Echocardiography, High-Intensity Interval Training, Cardiac Morphology

1. Background

Regular training goes in tandem with morphologic changes and cardiac function, known as "athlete's heart" (1). Athlete's heart is usually found during monitoring or tests for disease. Hypertrophy can be seen on echocardiography (2). Several echocardiographic investigations carried out on athletic or non-athletic individuals have shown 2 different models of athlete's heart. Eccentric hypertrophy develops left ventricular (LV) chamber size with a proportional enlargement in interventricular septal wall thickness (IVSW) due to volume overload associated with endurance training. Also, concentric hypertrophy increases LV ventricular wall thickness with no change in LV chamber size, which is due to pressure overload along with high systemic arterial pressure in resistance exercise (3).

Recent studies have demonstrated that cardiac modifications such as LV hypertrophy and stroke volume (SV) increase may be seen in individuals with a long-term exercise history (4). Some cardiac features such as IVSW and LV volume might be involved in these adaptations. Different types of training modalities such as pressure or volume overload can cause a variety of changes in cardiac characteristics (5). In other words, in athletes of resistive or strength sports, the ventricular walls are thicker, while there may be a slight or no increase in LV volume (6). Undoubtedly, echocardiography is the best noninvasive method to study LV hypertrophy. Echocardiographic results regarding exercise-induced LV hypertrophy are similar to magnetic resonance imaging and biopsy findings concerning the LV (7).

High-intensity interval training (HIIT) is a time-efficient alternative form of training to traditional endurance training and has been shown to confer similar benefits. For all the recent studies that have shown the effects of various types of physical activity on heart morphology and function, few investigators have examined the effects of HIIT so far (8, 9).

The purpose of the present study was to evaluate the effects of 10 weeks of HIIT on cardiac structure and function in healthy men as evaluated via echocardiography. Although the beneficial effects of endurance training in inducing physiological cardiac hypertrophy have been proven, we sought to investigate whether HIIT, which requires less time to do than other types of training, would also confer similar benefits. We also assessed morphologic pattern changes caused by HIIT with a view to developing the morganroth (10).

2. Objectives

The purpose of our study was to examine the effects of 10 weeks of HIIT on cardiac morphology and function at rest in young, healthy, previously untrained men.

3. Patients and Methods

The trial design was semi-experimental with a control group. Twenty-two young men (age = 23.34 ± 2.56 year, weight = 72.47 ± 12.01 kg, and height = 174.10 ± 5.75 cm) were randomized into either a training group (HIIT) or a control group. The CONSORT flow diagram is depicted in Figure 1. Informed consent was obtained from each patient included in the study, and the study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

3.1. Echocardiographic Evaluation

Echocardiography was performed using a Vivid 3 (GE, Vingmed, Horten, Norway) with a 3-MHz probe, with the subjects lying in the left decubitus position, by a single experienced echocardiologist. The data comprised the averages of 3 cardiac cycles. The evaluations were performed using previously published guidelines (11). M-mode measurements were done in the parasternal long-axis view. End-systolic volume (ESV), end-diastolic volume (EDV), left ventricular mass (LVM), and interventricular septal wall thickness (IVSWT) as morphological parameters and SV and ejection fraction (EF) as functional parameters were measured. LVM was calculated according to the Devereux formula (12). The echocardiographic procedures were studied and interpreted by cardiologists in Imam Reza hospital (Mashhad, Iran).

3.2. VO2max Estimation

The Bruce treadmill test was used for the estimation of VO_{2max}. This protocol is a maximal exercise test where the subject works to complete exhaustion as the treadmill speed and incline are increased every 3 minutes. The length of time on the treadmill is the test score and used to estimate the VO_{2max} value (13).

3.3. High-Intensity Interval Training Protocol

The HIIT group members were first acquainted with the correct training performances before they carried out the exercises, every other day, 3 sessions a week, for 10 weeks. The exercises included warm-up, HIIT training, and cool-down. The subjects warmed up by stretching and easy walking for 5 minutes. The HIIT interventions consisted of four 30-second maximal effort (all-out) shuttle-run bouts (from cone 1 to cone 2, 20-meter sweeps) separated by a 1.5-minute passive rest each.

The HIIT protocol commenced with 4 cycles/session, and 1 cycle was added every 2 weeks. Finally in the 10th week, the protocol reached 8 cycles/session, which lasted 16 minutes. cooling down also included 5 minutes of walking and stretching. During the HIIT interventions, all subjects were vocally encouraged to maintain maximal effort. The quality of training was controlled by a physical education expert, and the subjects' heartbeat was constantly checked with a polar device. The control group was asked to be sedentary in this period.

3.4. Limitations

We know that a longer period of duration/frequency of training can lead to more adaptation. Nevertheless, because the subjects were students, they were not able to cooperate in research more than 10 weeks. Furthermore, despite our encouraging the subjects throughout the test sessions, it cannot be guaranteed that they indeed made maximal effort.

3.5. Statistical Analysis

Data normality was tested using the Shapiro-Wilk test, and the homogeneity of the variances was tested using the Levene test. After the normality and equality of the groups was ensured, variance analysis with repeated measuring was used to study the differences between the groups. The statistical analyses were done using SPSS (version 20.0).

4. Results

After 10 weeks of HIIT, the subjects showed a significant increase in EDV ($P = 0.001$), LVM ($P = 0.002$), SV ($P = 0.003$), and EF ($P = 0.001$). However, there was no change in ESV due to HIIT ($P = 0.916$). Also, we observed that following HIIT, although there was a slight elevation in IVSWT ($P = 0.227$), it was not significantly different from pre-training levels (Table 1).

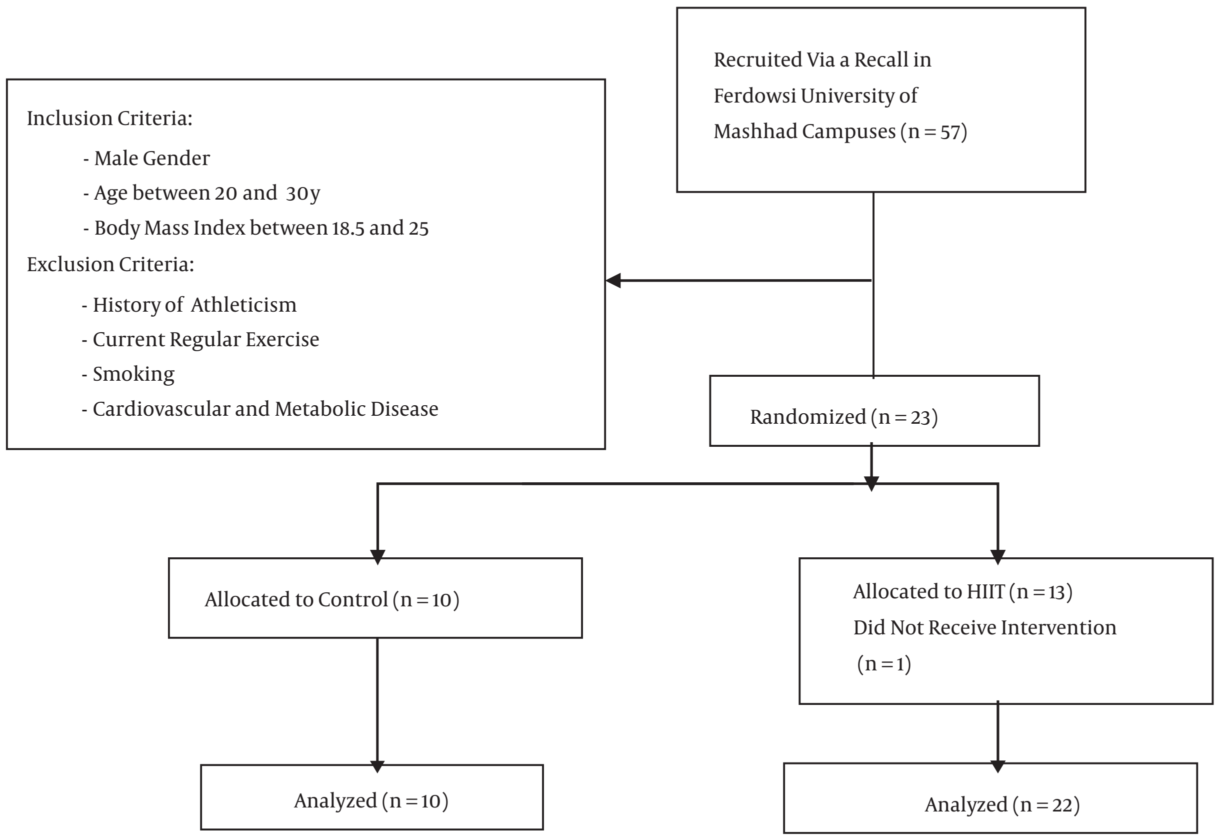

Figure 1. Consort Flow Diagram

Table 1. Cardiac Measures Before (pre) and After (post) 10 Weeks of the Study Protocol[a]

Variable	Control		HIIT		ANOVA[b]	
	Pretest	Posttest	Pretest	Posttest	F	P
LVM (g)	152.20 ± 9.53	152.60 ± 8.87	154.90 ± 7.23	163.83 ± 10.24	13.70	0.002
ESV (mL)	56.44 ± 2.00	56.50 ± 1.35	57.41±1.16	57.08 ± 1.44	0.1	0.916
EDV (mL)	130.70 ± 3.26	131.00 ± 3.95	135.09±3.61	141.90 ± 5.28	9.85	0.001
IVSWT (mm)	9.85 ± 0.40	9.88 ± 0.36	9.87±0.28	10.06 ± 0.25	1.56	0.227
SV (mL)	80.20 ± 2.89	80.20 ± 2.57	78.90±1.70	83.80 ± 4.31	12.11	0.003
EF (%)	57.70 ± 2.89	57.00 ± 3.39	56.91±2.10	60.00 ± 2.62	15.39	0.001
VO_{2max} (mL/kg/min)	35.60 ± 4.32	36.10 ± 3.92	37.58±3.62	50.25 ± 9.27	14.97	0.001

Abbreviations: EDV, end-diastolic volume; EF, ejection fraction; ESV, end-systolic volume; IVSW, interventricular septal wall thickness; LVM, left ventricular mass; SV, stroke volume.
[a]Data are presented as means ± SDs.
[b]Repeated Measurement.

5. Discussion

According to the findings of the present research, the mean of LVM, EDV, SV, and EF showed a significant increase due to the HIIT protocol, whereas no significant change was evident in ESV and IVSWT. These morphological changes were associated with a considerable increase

(33%) in aerobic power (VO_{2max}). Likewise, previous studies with similar HIIT protocols have observed a rise in VO_{2max} by 15% and 43% (14, 15).

Recent studies have demonstrated training-induced LV dilation for endurance protocols (6, 16). The results obtained in the present study concerning EDV and ESV are consistent with those reported by Sharma et al. (17). DuManoir et al. (18) reported a significant increase in LV dimensions, SV, and LVM following 10 weeks of high-intensity rowing.

Our data suggest that HIIT induced SV improvement without the accompanying augmentation of ESV and IVSW. As was mentioned, HIIT has features which generate unique hemodynamic loads (10, 19). Hemodynamic stress may underlie the changes observed in LV hypertrophy, which could involve a number of signaling pathways-including growth factors Akt and PI3K and trigger protein synthesis (20).

There is a dearth of data in the existing literature on the effects of HIIT on the morphology of the heart (8, 9). Unlike the present study, the protocols applied in previous studies, despite having HIIT characteristics, were not time-efficient (9) or merely assessed the early time-course of adaptation (8). The clinical implication of the results of the present research is that young healthy people by doing HIIT that takes just 16 minutes (3 sessions per wk for 10 wk) can gain cardiac physiological hypertrophy accompanied by enhanced aerobic power.

In summary, we undertook a randomized trial of the impact of 10 weeks of HIIT on LV morphology and function in previously untrained subjects. We aimed to develop a Morganroth hypothesis (10) by adding new data on HIIT-induced morphological changes in healthy subjects. The salient advantage of HIIT is time efficiency, so that people who are sedentary due to a lack of time can take advantage of its benefits (i.e., improved cardiac structure and aerobic power).

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