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Athlete's Heart in Israel: Fact or Fiction

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ABSTRACT: **Background:** The effects of exercise training on cardiac structure and function have been thoroughly investigated in athletes from sport-developed nations; few data are available on sportsmen from sport-developing countries.

Objectives: To assess the incidence and magnitude of the "athlete heart" phenomenon in an elite group of Israeli cyclists.

Methods: An echocardiography study was performed in 56 cyclists (49 males, mean age 38 ± 10 years, weekly average training 13.1 ± 5.9 hours); 96 sedentary subjects served as a control group.

Results: There were significant differences in left ventricular end-diastolic diameter (LVEDD) between cyclists and the control group (48 ± 4.7 mm vs. 45 ± 4.1 mm respectively, $P < 0.001$), as well as in inter-ventricular septum (IVS) thickness (9.9 ± 1.2 vs. 8.9 ± 1.2 mm, $P < 0.001$) and LV mass index (LVMI) (79 ± 16 vs. 68 ± 13 g/m^2, $P < 0.001$). In 5% of the cyclists LVEDD exceeded the upper normal limit of 56 mm. In 7% of the cyclists IVS thickness exceeded the upper normal limit of 11 mm. LV hypertrophy defined as LVMI ≥ 134 g/m^2 was absent in the entire cyclist group.

Conclusions: Endurance sport activity in well-trained Israeli sportsmen results in a modest increment in LV dimensions and LV mass. LV dilatation and wall thickness above values compatible with primary cardiac disease are rare. These results highlight that in Israeli athletes any abnormal echocardiographic value must be thoroughly investigated and not simply assumed to be a consequence of sport activities.

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KEY WORDS: athlete's heart, echocardiography, hypertrophy, incidence, remodeling

Intensive training induces structural and functional changes in the heart [1,2]. Morganroth et al. [3] were the first to describe two distinct morphological forms of athlete's heart: a strength-trained heart and an endurance-trained heart. Endurance training (also described as isotonic or aerobic) such as long-distance running produces an increment in the oxygen supply to the active muscle cells by increased cardiac output due to vascular dilatation and more efficient uptake of oxygen (higher arterio-venous oxygen difference), causing volume overload and eccentric hypertrophy (LV dilatation) [3-14]. On the other hand, strength exercise (also referred to as isometric) such as weightlifting results in little or no increase in oxygen uptake, producing predominantly higher wall tension, pressure overload and the resultant concentric LV hypertrophy [3-5,9,13,14]. Rowing and cycling represent typical strength and endurance sports involving combined dynamic and static exercise of large groups of muscles [15]. In highly trained sports people, excessive dilatation and thickness suggest a differential diagnosis between "athlete's heart" and a primary cardiac disease [4,5].

Although the changes in cardiac structure observed in trainee athletes was consistently proved in many studies [12-16], the degree of such changes, even when considering athletes in the same sporting discipline and training intensity, is less predictable. This inconsistent response to physical exercise among athletes is difficult to explain, other than the fact that genetic and environmental differences alter the physiologic response. National characteristics such as the type of sport practices, the frequency and intensity of training, and genetic and racial characteristics can all influence the degree of cardiac changes seen in athletes of a particular country [1]. Data on the characteristics of cardiac remodeling in countries less sport-developed, like Israel, are lacking. To the best of our knowledge, data regarding the Israeli sport-active population are also lacking.

The aim of the present study was to assess, by echocardiography, an elite sample of Israeli cyclists to determine the upper limits of LV diameter and LV wall thickness as a consequence of their combined dynamic and static physical activities. We also investigated potential factors that could influence the degree of cardiac remodeling.

SUBJECTS AND METHODS

We invited the best-trained cyclists from the membership lists of five of the leading cycling clubs in Israel to participate in the study. We enrolled only athletes who had not interrupted their exercise program for at least 3 months prior to the echocardiographic study. Anthropometric data and frequency and intensity of the training regimen were collected. None of the cyclists had any known cardiac or systemic disease. The control group, matched for age, gender, and body surface area, was

LV = left ventricular

healthy but sedentary. The study was approved by the local ethics committee for research in humans, and the participants signed an informed consent.

ECHOCARDIOGRAPHIC STUDY

The echocardiographic studies were performed at cycling clubs in different regions in central and southern Israel during the national competition season. The studies were done by an experienced sonographer (M.R.) using a portable device, Vivid I (General Electric Medical Systems, Horten, Norway), with capacity for a full standard echo study. The control group underwent a standard echo study at Soroka University Medical Center with a Vivid 7 digital ultrasound system. All measurements were done according to the American Society of Echocardiography guidelines [17]. Three cardiac cycles were stored in a cine loop format for offline analysis by an expert echocardiologist.

The following variables were studied in the present investigation: LV end-diastolic diameter and LV end-systolic diameter, inter-ventricular septum and posterior wall thickness, left atrium diameter, aortic root and ascending aorta diameter. We considered 56 mm as the upper limit of LVEDD and 11 mm as the maximal normal value for IVS and PW thickness. LV systolic function (eyeball estimation assessment) was defined as normal when LV ejection fraction was ≥ 50%. The LV diastolic function was assessed by spectral Doppler by measuring E and A wave velocities and the deceleration time of the E wave at the LV inflow tract and by tissue Doppler imaging of the lateral mitral annulus. LV mass was calculated using Devereux's formula [18] and indexed for BSA and height. LV hypertrophy was defined as an increment of LV mass index ≥ 134 g/m^2.The echocardiographic study was completed by searching for valvular pathologies using color and spectral Doppler.

STATISTICAL ANALYSIS

All values were expressed as mean ± SD. Subjects' characteristics and values obtained in the cyclist and control groups were compared using Student's unpaired test. *P* value < 0.05 was considered significant. Multivariate linear regression was used to assess the differences between the study and control group in echocardiographic parameters (LV mass, PW, IVS and LVEDD). The following variables were introduced into the model: study group, age, and BSA. Furthermore, we used linear regression models in the cyclists group to assess the association between average weekly training hours and echo parameters adjusted for age and BSA. Data analysis was performed using SPSS 18.0 statistical software for Windows (SPSS, Chicago, IL, USA).

LVEDD = LV end-diastolic diameter
LVESD = LV end-systolic diameter
IVS = inter-ventricular septum
PW = posterior wall
BSA = body surface area

RESULTS

Fifty-six cyclists, 49 males and 7 females with a mean age of 38 years (range 21–56 years), were included in the study. Five of them ranked among the top 10 in the Israel Cycling League. The control group comprised 96 individuals (87 males). The cyclists exercised an average of 5 times a week, with a weekly average of 13.1 ± 5.9 hours training. The study groups did not differ in baseline clinical characteristics [Table 1].

ECHOCARDIOGRAPHIC CHARACTERISTICS

There were statistically significant differences between the cyclists and the control group in all the echocardiographic parameters evaluated, except for LVESD which was similar between the groups [Table 2]. Although LV dimension and

LVSD = LV end-systolic diameter

Table 1. Clinical characteristics of the cyclists study group and control group

	Cyclists group Mean (SD) (n=56)	Control group Mean (SD) (n=96)	*P* Value
Age (yr)	37.5 ± 9.6	35.5 ± 8.8	0.177
Weight (kg)	72 ± 10.2	73.5 ± 10.3	0.371
Height (cm)	175 ± 7.1	173 ± 9.2	0.153
BSA (m^2)	1.87 ± 0.16	1.86 ± 0.16	0.697
Males (%)	88	92	0.316
Rest pulse (bpm)	54 ± 9.7	66 ± 12.3	< 0.001

bpm = beats per minute, BSA = body surface area

Table 2. Comparison of echocardiographic characteristics between the study group and the control

		Cyclists group mean ± SD (range) (n=56)	Control group mean ± SD (range) (n=96)	*P* value
PW thickness (mm)		7.9 ± 1.2 (6–10)	8.4 ± 1.2 (5–11)	0.011
IVS thickness (mm)		9.9 ± 1.2 (7–12)	8.8 ± 1.2 (6–11)	< 0.001
LVEDD (mm)		48 ± 4.7 (37–57)	45 ± 4.1 (36–55)	< 0.001
LVESD (mm)		28 ± 4.1 (20–38)	27 ± 3.4 (18–36)	0.065
Left atrium diameter (mm)	Superior-inferior	50 ± 5.2 (41–63)	43 ± 4.5 (33–53)	< 0.001
	Anterior-posterior	37 ± 3.9 (31–47)	32 ± 3.7 (23–43)	< 0.001
Aortic root diameter (mm)		23 ± 2.36 (16–27)	21 ± 2.37 (16–26)	< 0.001
Ascending aorta diameter (mm)		31 ± 2.8 (26–36)	29 ± 3.1 (22–35)	< 0.001
Right atrium diameter (mm)		48 ± 6 (33–61)	43 ± 4.8 (22–53)	< 0.001
LV mass (gm)		147 ± 35.2 (82–221)	127 ± 27.4 (75–194)	< 0.001
LV mass/BSA (g/m^2)		79 ± 16.3 (51–115)	68 ± 12.7 (40–103)	< 0.001

BSA = body surface area, IVS = inter-ventricular septum, LV = left ventricle, LVEED = left ventricular end-diastolic diameter, LVESD = left ventricular end-systolic diameter, PW = posterior wall

Table 3. Multivariable analysis for echocardiographic variables: results of multivariate linear regression

	LV mass		PW thickness		IVS thickness		LVEDD	
	B	*P* value	B	*P* value	B	*P* value	B	*P* value
Cyclists vs. control	19.34	< 0.001	-0.471	0.018	1.000	< 0.001	2.674	< 0.001
BSA	82.74	< 0.001	1.417	0.047	1.425	0.032	11.680	< 0.001
Gender (female vs. male)	-13.47	0.101	-0.231	0.519	-0.857	0.011	-0.684	0.580
Age	0.289	0.230	-0.001	0.915	0.024	0.015	0.004	0.970

BSA = body surface area, IVS = inter-ventricular septum, LV = left ventricle, LVEED = left ventricular end-diastolic diameter, PW = posterior wall

Table 4. Multivariable analysis of the cyclists group for echocardiographic variables: results of linear regression

	LV mass		PW		IVS		LVEDD	
	B	*P* value	B	*P* value	B	*P* value	B	*P* value
BSA	109.93	0.005	3.593	0.016	0.176	0.894	13.483	0.016
Gender (female vs. male)	-17.081	0.329	0.363	0.590	-1.713	0.008	-1.371	0.589
Age	-0.146	0.748	-0.028	0.110	0.003	0.852	0.025	0.705
Total hours exercise	1.138	0.120	0.016	0.560	0.052	0.049	0.094	0.375

BSA = body surface area, IVS = inter-ventricular septum; LV = left ventricle, LVEED = left ventricular end-diastolic diameter, PW = posterior wall

wall thickness were higher in the cyclists, values above the upper normal limits were rare. LVEDD of 57 mm, above the normal limit of 56 mm, was seen in only 3 cyclists (5%). In 13 (23%) IVS reached the upper normal limit of 11 mm, and in only 4 (7%) IVS measured 12 mm. PW and LV mass index values were within normal limits in all the cyclists without exception.

FACTORS RELATED TO CARDIAC REMODELING

Statistically significant differences were found between the cyclists group and the control group in LV mass, IVS and LVEDD ($P < 0.001$), as well as in PW thickness ($P = 0.018$), adjusted for BSA, age and gender as assessed by multivariate linear regression analysis [Table 3]. In addition, BSA was found to be an independent parameter that significantly correlated with all echocardiographic parameters, both in the cyclists and the control group. For the cyclists group, the average weekly hours of training correlated significantly with IVS thickness ($P = 0.049$), adjusted for BSA, gender and age of the cyclists, but no significant correlation was found between average hours of training and other echocardiographic parameters such as LV mass, PW and LVEDD [Table 4]. In both models, for both groups and for the cyclists group only [Tables 3 and 4], women had a significantly lower IVS thickness compared to men ($B = -0.857$, $P = 0.011$, $B = -1.713$, $P = 0.008$, respectively).

DISCUSSION

Our study demonstrates that in top-ranked Israeli cyclists, intense exercise causes changes in cardiac anatomy as assessed by echocardiography. Indeed, significant differences were found between the cyclists and the control group, which can be interpreted as concentric cardiac remodeling (LV mass index 79 ± 16 and 68 ± 13 g/m^2 respectively, $P < 0.001$) and eccentric cardiac remodeling (LVEDD 48 ± 4.7 and 45 ± 4.1 mm respectively, $P < 0.001$). Sport activity was related to increased concentric and eccentric hypertrophy, independent of age, gender and BSA.

Cycling is one of the highest endurance sport activities and is popular in Israel. Thus, if cardiac remodeling due to sport develops in Israeli athletes, it is plausible to expect the maximum spectrum of this phenomenon in our studied population. Indeed, we demonstrated that in Israeli cyclists exercise had an effect on cardiac anatomy; however, the magnitude of cardiac remodeling in our study is significantly lower than data previously published for cyclists in countries considered leaders in cycling [19-21]. LV wall thickness above 11 mm was observed in only 7% in our cyclist population as compared to more than 16% among cyclists in the UK found by Basavarajaiah et al. [19]. In the review by Pluim and co-authors [20] of 17 studies on cyclists' echocardiographic characteristics, the LV mass was substantially greater (233–316 g) than in our cyclists group (147 ± 35 g). Lo et al. [21] studied LV hypertrophy in professional Chinese cyclists and observed a mean LV mass index of 161 ± 20 g/m^2, which was much higher than in Israeli cyclists (78 ± 16 g/m^2).

The modest cardiac remodeling in this study may be explained by the presumed inferior performance of Israeli cyclists, where cyclists are amateurs and not professionals. Nonetheless, our study population represents high level Israeli trainee sportsmen, as evidenced by the study of Fuchs et al. [22] of 92 competitive athletes training at Israel's Wingate Institute of Sport who exercised an average of 7.1 hours weekly. By linear regression analysis, weekly hours of training was an independent factor that affected at least part of the evaluated cardiac parameters (IVS thickness) in the Israeli cyclist. Probably, the main differences between our studied population and the non-Israeli cyclists are the regimen and intensity of training. Since there are no data on the training regimen in the previously published works, our hypothesis could not be tested. In clinical practice, it is reasonable to consider that an abnormal echocardiographic value would have a different significance in countries with higher cardiac remodeling than in countries with less cardiac adaptation to sport. While a substantially high increment of LV dimensions and wall thickness may be considered a physiological adaptation to sport in elite athletes from countries such as the USA, the UK, France and China, a high index of suspicion for cardiac disease is warranted when any abnormal echocardiographic measurement is found among elite Israeli athletes.

Studies on echocardiographic characteristics in female athletes are scarce and the effect of intense physical activity on cardiac changes in females is less understood. In our study a multivariate linear regression showed a significant difference in echocardiographic characteristics between females and males, but only in IVS thickness ($P = 0.008$). It is possible that a larger cohort of female cyclists would have demonstrated statistical significance for other echocardiographic characteristics. Since the number of female cyclists who participated in this study was low, our conclusions are limited to male gender.

STUDY LIMITATIONS

We had no data on the participants' aerobic capacity. If there is any relationship between aerobic capacity and magnitude of cardiac remodeling it would help to predict the magnitude of remodeling in our studied population and perhaps explain, at least partially, the differences between Israeli and non-Israeli cyclists.

CONCLUSIONS

Cardiac enlargement in Israeli top-ranking cyclists is a frequent echocardiographic finding. Distinctly abnormal dilatation compatible with primary cardiac disease is an uncommon finding. These results emphasize that any echocardiography measurement above the normal upper limits in Israeli athletes must be thoroughly investigated and should not be assumed to be a consequence of their physical activity. A similar study in other less sport-developed countries is warranted to extend our conclusions to athletes worldwide.

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"One of the oldest human needs is having someone to wonder where you are when you don't come home at night"

Margaret Mead (1901-1978), American cultural anthropologist. She was a respected, if controversial, academic anthropologist. Her reports about the attitudes towards sex in South Pacific and Southeast Asian traditional cultures amply informed the 1960s sexual revolution