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Research Paper

Echocardiographic Assessment of Elite Athletes as Surrogate of the Magnitude and Prevalence of Cardiac Remodeling due to Sports.

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ABSTRACT

Background: Enlargement of the cardiac chambers and hypertrophy of the left ventricular (LV) walls is often seen among athletes as a consequence of intensive training and varies among nations. We assessed Israeli Olympic athletes by echocardiography as a survey of the magnitude and prevalence of physiologic cardiac remodeling.
Methods: Seventy-eight trained Olympic sports participants underwent an echocardiography study: 50 males, 28 females, mean age 22 years (range 14-30). They participated in 15 different sports: 49% in endurance disciplines, 23% in resistance sports and 28% in mixed disciplines.
Results: LV end-diastolic diameter (LVEDD) range was 44-61mm (mean 51mm). In 81% of the participants, LV dimension was normal, 19% exceeding the upper normal limit of 56mm, but in only 4 of the 78 athletes did LVEDD reach 60mm or more. LV dimension was unrelated to type of sport, but principally to body surface area (BSA): 2.04 $\pm$ 0.22 m^2 and 1.73 $\pm$ 0.20m^2 for those with LVEDD >56mm and $\leq$56mm, respectively (p<0.001). Interventricular septum (IVS) thickening was 8.9 $\pm$ 1.4mm. In 2 of the 78 participants, IVS was as high as 13mm, but none exceeded 13mm. Posterior wall thickening was normal in all participants: 9 $\pm$ 1.5mm. LV hypertrophy according to LV mass/index was present in 3% of the studied population. Echocardiographic values above the upper normal limit were seen only in males.
Conclusions: Enlargement of LV occurs in a substantial proportion of highly trained athletes, however this phenomenon was observed only in males. Distinctly abnormal dimension found in patients with cardiomyopathy is an uncommon finding among elite Israeli athletes and LV hypertrophy is rare. Then, careful assessment of primary cardiac disease is warranted in sportsmen with markedly abnormal echocardiographic values.

Key words: athletes heart, echocardiography, cardiomyopathy, remodeling.

INTRODUCTION

Intensive training induces structural and functional changes in the heart [1-4]. The adaptive changes seen in the athlete's heart are enlarged left ventricular (LV) diastolic dimension and increased LV wall thickness. The physiologic limits of remodeling are altered by gender, type of sport, training intensity, genetics and race [4-6].
Although the changes in cardiac structure observed in trainee athletes have been consistently shown in many studies [1-6], the degree of such changes, also when considering athletes in the same sport discipline and training intensity, is less predictable. National characteristics like type of sport practices, frequency and intensity of training, genetic and race characteristics can all influence the degree of cardiac changes seen in athletes of a particular country [12]. Then, the prevalence and degree of cardiac remodeling due to sport activities varies between nations. Knowledge of the magnitude and frequency of cardiac changes in sportsmen of a determine country can help physicians to manage those athletes in whom the diagnosis between "athlete heart" and a primary cardiac disease is less clear. Potentially, in nations with low prevalence of "athlete heart" physicians must be careful to qualify as physiologic remodeling of the heart any abnormal echocardiographic study among the athletic population.

Therefore, we assessed an elite sample of Israeli Olympic athletes, representative of the highest level national competitors by echocardiography, to assess the upper limits of LV diameter and LV wall thickness as a surrogate of the magnitude and prevalence of cardiac remodeling in women and men participating in sports activity in Israel and compared the results to countries with outstanding sports achievements. We also investigated potential factors that can influence the degree of cardiac remodeling.

METHODS

Population and study design

This was an observational study of athletes, members of the Israeli Olympic team. The participants underwent an echocardiography study during a period of intense training coinciding with their preparation for the upcoming event. We considered for investigation only the athletes who did not interrupt their exercise program for at least the last 3 months prior to the echocardiographic study. The studies were performed at the Ribstein Center for Sport Medicine Research, Wingate Institute, Netanya. Physiologic parameters and laboratory data were obtained from the athletes' medical records. Seventy-eight athletes of the Israeli Olympic team, 8 of them holding leading positions in their respective disciplines during the Olympic Games, were included in the study: 50 males, 28 females, and age 14-30 years (mean 22). They participated in 15 different sports that were classified as endurance exercise (49% of the participants), resistance sport (23% of the athletes) and mixed disciplines (28% of the sample).

Echocardiography study

The echocardiographic studies were performed by an expert sonographer and later evaluated by a cardiologist. All measurements were made according to the American Society of Echocardiography guidelines [13]. The following echocardiographic variables were studied in the present investigation: left atrium (LA) dimensions, aortic root diameter, LV end-diastolic and end-systolic internal dimensions, interventricular septum (IVS) and posterior wall (PW) thickness. We considered 56mm as the upper limit of LVEDD and 11mm as the maximal normal value for IVS and PW thickness. LV mass was calculated according to Devereux method and adjusted to body surface area (BSA): LV mass/index [14]. LV hypertrophy was defined as an increment of LV mass index ≥ 134gr/m^2 and ≥ 110gr/m^2 for male and female, respectively. The echocardiographic study was completed by searching for cardiac pathologies using Color and spectral Doppler.

Definitions of types of sport

Endurance sport: repetitive contraction of muscles that change length. Peripheral resistance falls and intra vascular volume increases enhancing stroke volume, consequently cardiac output rises. The cardiac compensatory response to volume overload is eccentric LV hypertrophy (increased LV internal dimension) [2].
Resistance sport: sustained contraction of muscles without change in length. Increase in sympathetic tone results in systemic vasoconstriction. To compensate the pressure overload, the heart increases its mass (concentric LV hypertrophy) [11].
Mixed discipline: combination of repetitive and sustained muscle contraction [2].

Statistical analysis

Clinical variables were converted into categorical variables and chi-square statistical analysis was used to compare the variables between the groups. A univariate analysis was then performed to identify risk factors for the development of LV dilatation and hypertrophy in our subjects. Categorical variables were evaluated using the Chi square test, or other aparametric tests, as applicable. Continuous variables were evaluated using students t-test or Mann-Whitney test as appropriate. Using the data retrieved from our univariate analysis, we continued with a multivariate linear regression analysis to determine a model of risk for developing LV dilatation. Variables that were statistically significant in the univariate analysis as well as other presumed confounding variables were included, and an Enter selection process was applied to find the significant explanatory variables for the model. Data analysis was performed using SPSS 13.0 statistical software for Windows (SPSS, Chicago, IL, USA).

RESULTS

Seventy-eight Olympic athletes were assessed by echocardiography. No athletes had history of systemic hypertension. The average height and weight of the athletes was 171 ± 10 cm and 67 ± 14 kg, respectively. Their hemoglobin level was 14 ± 0.9 gr/dl.

Echocardiographic characteristics

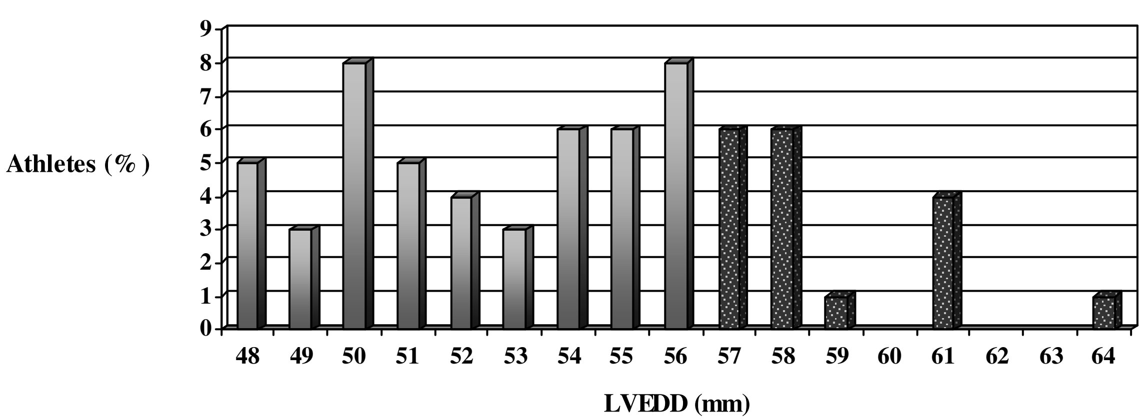
Most the athletes had echocardiographic values within normal limits. Table 1 summarizes the echocardiographic parameters of the overall population. Fifteen (19%) athletes had LVEDD >56mm and in 4 (5%) of them LVEDD was ≥60mm (Figure 1). In 11 (14%) athletes IVS reached the upper normal limit of 11mm but in one, IVS measured 12mm and in other athlete 13mm. PW was ≤11mm in all the cases. LV hypertrophy defined as LV mass/index ≥ 134gr/m^2 and ≥ 110gr/m^2 for male and female, respectively was found in 2 male athletes (3% of the studied population). No difference in heart rate, blood pressure and laboratory parameters were found between those with normal and abnormal echocardiographic values. No significant valvular and non-valvular cardiac diseases were identified in any of the athletes.

Table 1: Echocardiographic characteristics.

ECHOCARDIOGRAPHIC PARAMETERS	ALL POPULATION (N=78)	MALES (N=50)	FEMALES (N=28)	P VALUE*
Septum (mm)	9.0 ± 1.3	9.5 ± 1.2	8.2 ± 0.9	<0.001
Posterior wall (mm)	9.0 ± 1.0	9.4 ± 1.0	8.4 ± 0.8	<0.001
LVEDD (mm)	52.0 ± 5.0	54.0 ± 4.8	48.0 ± 2.7	<0.001
LVESD (mm)	32.0 ± 4.2	33 ± 4.3	29 ± 2.6	<0.001
LV mass/index (gr/m2)	94.0 ± 19.0	101.0 ± 18.0	81.0 ± 11.0	<0.001
Left atrium (mm)	34 ± 4.0	36 ± 4	32 ± 2.6	<0.001
Aortic root (mm)	29.0 ± 3.3	31 ± 3	27 ± 3	<0.001

LVEED= Left ventricular end=diastolic diameter; LVESD= Left ventricular end-systolic diameter. *Unpaired t-test

Figure 1. Left ventricular end-diastolic diameter in the 78 athletes.



Legend: In scarified bars the values that are out of the normal. They represent 19% of the studied population that showed left ventricular end-diastolic diameter (LVEDD) ›56mm.

Echocardiography results and gender

All the echocardiographic parameters assessed in the 28 females were within normal limits. Males had significantly larger LV internal dimensions, thicker ventricular walls and increased LV mass compared to females as shown in Table 1. Significantly more males participated in endurance activities than females: 60% versus 28% in females ($p<0.001$). When comparing the echocardiographic characteristics by gender only for those who participated in endurance sports the difference in LVEDD (54 ± 5mm vs. 48 ±3mm, $p <0.001$), IVS (9.5 ± 1.3mm vs. 8.2 ± .9mm, $p<0.001$), LV mass index (101 ± 18gr/m^2 vs. 81 ± 11gr/m^2, $p<0.001$) were significant. There is no data on type, and intensity of training of male and female for the same sport disciplines.

Echocardiography results and type of sport

There was no significant difference in the echocardiographic values between athletes that participated in endurance and resistance disciplines as depicted in Table 2. Indeed, LV dimension and wall thickness were similar between groups. Because the proportion of females who participated in endurance and resistance activities was different (28% versus 60%, respectively) we evaluated males separately according to type of sport. No significant difference in the cardiac structure was observed in males between those who participated in endurance, resistance and mixed sports.

Table 2: Echocardiographic characteristics by type of sport.

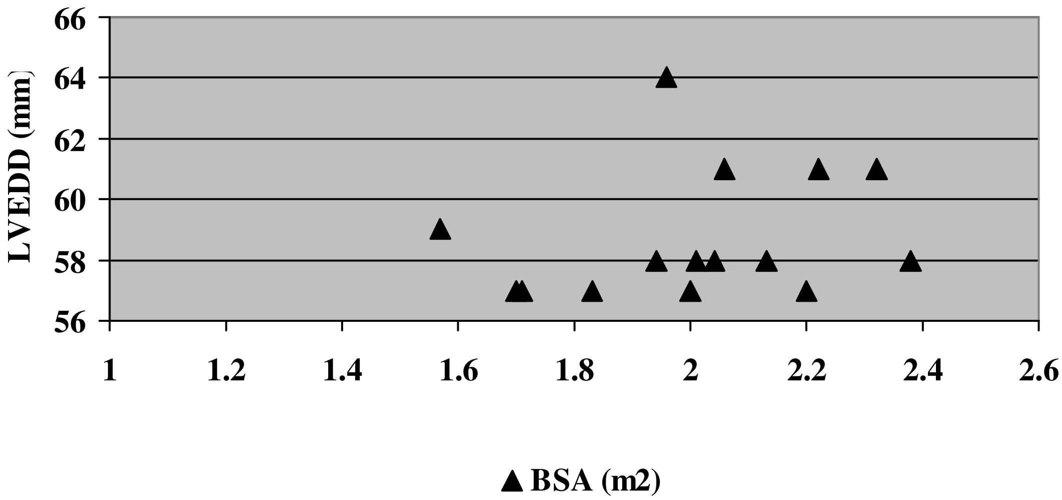
ECHOCARDIOGRAPHIC PARAMETERS	ENDURANCE (N=38)	RESISTANCE (N=18)	MIXED (N=22)	P – VALUE **
Septum (mm)	9.3 ± 1.2	9.1 ± 1.3	8.3 ± 1.0	0.008
Posterior wall (mm)	9.2 ± 1.0	9.1 ± 1.0	8.7 ± 1.0	0.174
LVEDD (mm)	51.6 ± 5.1	53.3 ± 5.2	49.6 ± 4.3	0.064
LVESD (mm)	31.9 ± 4.1	33.5 ± 5.2	30.4 ± 3.0	0.066
LV mass/index (gr/m2)	97.2 ± 18.0	98.0 ± 19.5	84.5 ± 16.7	0.02
Left atrium (mm)	34.4 ± 3.7	36 ± 4.9	33 ± 3.2	0.027
Aortic root (mm)	29.3 ± 3.4	30.8 ± 2.3	28 ± 3	0.02

LVEED= Left ventricular end=diastolic diameter; LVESD= Left ventricular end-systolic diameter. **One way ANOVA

Multivariable analysis

We compared those athletes (n=15) who had LVEDD greater than 56mm to those (n=53) with normal LVEDD (≤ 56mm). They had similar clinical characteristics except for their BSA: 2.04 ± 0.22m^2 and 1.73 ± 0.20m^2 for those with LVEDD >56mm and ≤56mm, respectively ($p<0.001$). All the athletes with a LVEDD >56mm had a BSA equal or greater than 1.8m^2 except 2 cases (Figure 2). By multiple regression analysis the only significant predictor of LVEDD was BSA ($p<0.001$). By correlation coefficient BSA was a significant factor related to LVEDD (0.67).

Figure 2. Left ventricular end-diastolic diameter (LVEDD) and BSA correlation



Legend: Fifteen athletes had left ventricular end-diastolic diameter (LVEDD) ›56mm. There were only 2 athletes (outside the circle) with body surface area (BSA) ‹1.8m^2

DISCUSSION

Using echocardiography we have shown in Israeli elite athletes that LV end-diastolic dilatation occurs in a considerable proportion of highly trained male athletes, and that it is unrelated to the type of activity. Indeed, in 19% of the studied population, LVEDD exceeded the upper normal limit of 56mm. However, distinctly abnormal dilatation (LVEDD ≥60 mm) compatible with pathologic conditions was an uncommon finding (5%). The absolute values of the LV dimensions and the proportion of athletes with dilated LV were lower than those published by other authors. Pelliccia and colleagues showed that 24% of Italian athletes had LVEDD greater than 56mm, 10% greater than 60mm, and maximal LVEDD was 68mm [5]. Our study population participated in 15 different sports of which the 3 most common were swimming, Ti Kwan Do, and Judo. High endurance sports, namely cycling, pentathlon were not included in our population. This may partially explain the differences between Pelliccia's results and ours.

In our study only males showed cardiac dimensions that overlap with cardiac primary disease raising the differential diagnosis between both situations. This is consistent with previous studies that have shown that in females cardiac remodeling due to physical activity is usually minor. Indeed, Pelliccia et al showed that the degree of cardiac remodeling due to sport in males is more prominent than in females showing significant differences in cardiac dimensions [5]. Left ventricular dimension exceeding normal limits was present in a minority (8%) of female athletes and markedly dilated LV cavity, namely ≤ 60mm at end-diastole was exceptional (1% of athletes). LV wall thickness was within normal limits for all females athletes [6]. In our study, no athlete woman had echocardiographic values above the normal limits.

The particular type of sport had no significant impact on LV dimension in our athlete population. Those who participated in endurance disciplines that cause eccentric hypertrophy did not show higher LV diastolic dimension than those who participated in resistance sport. Spirito and colleagues showed that cyclists had the most significant cardiac remodeling changes followed by triathlons participants as well as weight lifting athletes who more frequently developed concentric LV hypertrophy [18]. Our study sample did not include athletes involved in the most strenuous and resistance disciplines that are the most likely to predispose to significant cardiac changes.

By multivariable analysis we concluded that the only factor associated with LV diastolic dimension above upper limit was BSA. When considering BSA, we noted that most of the cases with a LVEDD >56mm had a BSA equal or greater than 1.8m^2 except for 2 athletes (Figure 2). Therefore, a high index of suspicion for primary cardiac disease must be raised when LVEDD above normal occurs in athletes with BSA less than 1.8m^2. And differentiation of athlete's heart and primary cardiac disease appears to be a diagnostic dilemma that is limited to male athletes, at least based on the population investigated in the present study.

Clinical implications

There is significant variation in the magnitude and prevalence of cardiac changes due to sports activities among athletes from different countries. In nations with low frequency of "athlete hearts" physicians must carry a deep investigation of primary cardiac disease among athletes with markedly abnormal echocardiographic study. Nations must have their own survey on the frequency and degree of cardiac remodeling due to sport and not extrapolate data from other countries.

CONCLUSIONS

Cardiac enlargement in Israeli elite athletes is a frequent echocardiographic finding in males and is absent in females. Distinctly abnormal dilatation compatible with primary cardiac disease is an uncommon finding. Body surface area and not type of sport is related to increment in LV dimensions. A similar study including more endurance and resistance disciplines is warranted in order to extend our conclusions to all Israeli athletes.

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