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Echocardiographic assessment of children participating in regular sports training

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ABSTRACT

OBJECTIVE: The aim of the present study was to determine the effects of a well-controlled endurance training program on cardiac functions and structures in healthy children and to define whether training hours per week and type of sports affect the training-induced cardiovascular response.

METHODS: Echocardiographic recordings were obtained in 126 children who systematically participated in sports training at least for 1 year (Study group) and the results were compared with the values obtained in 62 normal children who did not actively engage in any sports activity (Control group). The two groups were comparable for age, sex and body mass index. Study group participants were divided into two groups according to the duration of physical activity (training hours per week; less than 8 hours and more than 8 hours) and five groups according to cardiovascular demand of sports type. Clinical examination, resting ECG, two dimensional, M Mode and Doppler-echocardiography were obtained in all participants.

RESULTS: Left ventricle wall dimensions, left atrial diameter and aortic measurements were significantly higher in study group. The mean mitral E/A ratio was also significantly higher in training group compared with the untrained subjects ($p < 0.001$). Echocardiographic measurements were similar between different sports type participants in study group. However, aortic root diameter, left atrial diameter and left ventricle posterior wall diastolic thickness were higher in children training > 8 hours compared with the children training <8 hours per week in study group.

CONCLUSION: This study showed that echocardiographic parameters of children participating in regular sports training activities statistically significantly exceeded the parameters of untrained controls. These parameters were mostly dependent on the duration of training hours per week.

Keywords: Athlete's heart; children; echocardiography; sports activity.

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"Athletes heart' is known as the myocardial hypertrophy due to regular and intensive physical exercise. This condition is physiological, adaptive and reversible [1]. It is also well documented that myocardial remodeling is related to the intensity and kind of sport practiced [2]. The relationship between different sports type and cardiac structure especially in adults has been investigated in many studies before [3, 4]. However, there are few studies in children and adolescents about the effects of sports training on cardiac functions and structure [5]. Short-term training sessions have been shown to result in significant structural and functional cardiac adaptations including increases in left ventricular posterior wall diameter and interventricular septum thickness in children [6]. Very recently, Zdravkovic et al. investigated the electrocardiographic changes in preadolescent footballers

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and reported significant differences between footballers and control group regarding P-wave, S-wave and R-wave voltages, wave duration and QTc interval duration which were considered as the ECG pattern of LV remodeling since those athletes did not develop any adverse cardiac events in 6-year follow-up [7]. In that aspect, it is important to find out the impact of regular exercise and the remodeling period on children's heart which is still in maturation period.

The aim of this study is to determine the effects of regular exercise on the child's heart and to define whether training hours per week or type of sports affects the training-induced cardiovascular response in training children.

Increasing cardiovascular demand		
↓	Low	Billiards, bowling, cricket, curling, golf
↓	Low moderate	Diving, table tennis, volleyball, motorcycling
↓	Moderate	Gymnastics,weight lifting, synchronized swimming, orienteering, running, tennis
↓	High moderate	Bodybuilding, wrestling, basketball, snowboarding, team handball
↓	High	Boxing, cycling, decathlon, rowing

FIGURE 1. Classification of sports according to cardiovascular demand.

MATERIALS AND METHODS

From February 2016 to December 2016, 126 children who systematically participated in sports training at least for 1 year (Study group) and 62 normal children who did not actively engage in sports (Control group) were enrolled in this prospective, case control study.

Children with congenital heart disease, arrhythmia associated chronic diseases (obesity, hypertension, diabetes mellitus etc.), and children who were under regular medications were excluded from the study. Study group participants were divided into two groups according to the duration of physical activity (training hours per week; less than 8 hours and more than 8 hours) and five groups according to cardiovascular demand of sports type [2]. This classification allows classifying sports type according to cardiovascular demand. The lowest total cardiovascular demands (cardiac output and blood pressure) are shown in green and the highest in red. Blue, yellow, and orange depict low moderate, moderate, and high moderate total cardiovascular demands [2] (Figure 1).

All participants had a clinical examination, resting ECG, two dimensional, M Mode and Doppler-echocardiography.

Echocardiographic examination

Echocardiography was performed using the Vivid 3 (General Electric, USA) echocardiography by the aid of 3 MHz probes. All echocardiographic examinations were performed by one experienced pediatric cardiologist who was blinded as to the training status of participants in order to avoid inter-observer variability, from the long axis view and following the American Heart Association echo guidelines [8]. The standard left ventricle (LV) 2D parameters were obtained at rest. The basal 2D systo-diastolic and Doppler parameters, inter ventricular septum (IVS) and posterior wall (PW) thickness, left ventricle end-diastolic diameter (LVEDd), left ventricle end-systolic diameter (LVESd), left atrium (LA), aortic root (AR) and ascending aorta (AA) dimensions, pulse wave Doppler transmitral flow E-wave, A-wave (E/A ratio) were recorded. Mitral E/A ratio was used as an diastolic index of left ventricle. The assessment of systolic function of myocardium was made by measurement of the ejection fraction (EF%) which was obtained according to formula ((LVEDd)3-(LVESd)3/(LVEDd)3*100), and percentage of the shortening of the left ventricle (FS %) (LVEDd-LVESd/LVEDd*100).

Statistical analyses

Statistical analyses were performed with the SPSS 22 for Windows software. All data were expressed as mean±SD. The echocardiographic variables were compared between study and control groups by the Student's t-test and Mann Whitney U tests. Study group comparison according to sports type were performed by Kruskall Wallis variance analysis test. The $p<0.05$ was regarded as statistically significant.

Ethical approval

All study procedures were approved by the Ethics Committee of a tertiary center (2012-KAEK-15/1322). Written informed consent was obtained from all subjects and their parents and the study conformed to the Declaration of Helsinki.

TABLE 1. Comparison of demographic characterics among groups

	Study group (n=126)	Control group (n=62)	p
Age (months)	162.3±31.9	162.3±31.1	0.99
Height (cm)	160.7±16.4	157.4±13.3	0.16
Weight (kg)	53.4±16.9	50.3±12.5	0.20
BMI(kg/m^2)	20.1±3.6	20±3.18	0.80
SBP (mmHg)	113.6±10.4	112.1±10.3	0.36
DBP (mmHg)	63.2±8.2	65±7.4	0.15
HR (bpm)	83.9±13.3	91.8±14.2	0.01

BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HR: Heart rate.

TABLE 2. Comparison of echocardiographic parameters among groups

	Study group (n=126)	Control group (n=62)	p
AR mm	22.6±3.5	21.5±2.6	0.02
AA mm	21.1±2.8	20.3±2.1	0.03
LAD mm	27.2±4.1	25.2±3.4	0.01
EF %	71.8±5.6	71.2±6.2	0.49
FS%	41±4.8	40.5±5.2	0.55
LVEDd mm	43±5.7	42.8±4	0.77
LVESd mm	25.3±4.4	25.1±3.9	0.79
IVSD mm	10.5±2.2	9.2±2.1	0.01
IVSS mm	13.5±2.4	12.1±2.1	0.01
LPWd mm	9.6±2.2	7.8±1.7	0.01
LPWs mm	15.3±3.1	13.3±3.7	0.01
Mitral E/A	1.9±0.2	1.6±0.2	0.01

AR: Aortic root; AA: Asendan aorta; LAD: Left atrial diameter; EF: Ejection fraction; FS: Shortening fraction; LVEDd: Left ventricle end diastolic diameter; LVESd: Left ventricle end sistolic diameter; IVSD: Interventriculer septum in diastole; IVSS: Interventriculer septum in systole; LPWD: left ventricle posterior wall thickness in diastole; LPWs: left ventricle posterior wall thickness in systole.

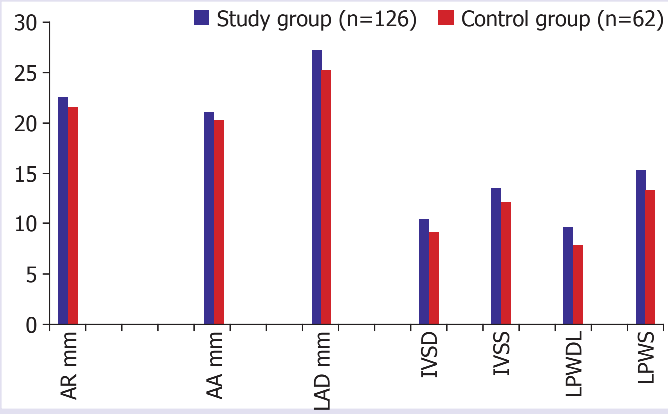

FIGURE 2. Alterations in some echocardiographic parameters among 2 groups. AR: Aortic root; AA: Asendan aorta; IVSD: Interventriculer septum diameter in diastole; IVSS: Interventriculer septum diameter in systole; LPWD: Left ventricle posterior wall diameter in diastole; LPWS: Left ventricle posterior wall diameter in systole.

RESULTS

Demographic and general characteristics of study participants are defined in Table 1. There were no statistically significant differences between study and control groups regarding age, gender, height, weight and BMI. Resting systolic and diastolic blood pressures were also similar. Heart rate was lower in study group (p=0.01) (Table 1).

The echocardiographic measurements of aortic dimensions; AR and AA were significantly higher in study group (p=0.02, p=0.03 respectively). Echocardiographic analyses of left heart showed that the values of the left atrium (LA), left ventricle posterior wall thickness in diastole (LVPWd) and left ventricle posterior wall thickness in systole (LVPWs) were statistically significantly increased in study group (p=0.01) (Table 2, Figure 2).

The values of septum thickness in systole (IVSs), septum thickness in diastole (IVSd) and Mitral E/A ratio were also found higher in study group (p=0.01).

Contractibility parameters (EF%, FS%) and left ventricular end-diastolic dimension (LVEDd), left ventricular end-systolic dimension (LVESd) were higher in study group, but the differences between 2 groups were not statistically significant.

When study group was assessed according to training hours per week, all echocardiographic measurements were higher in group training more than eight hours. However, only measurements of LVPWd , LA and AR were statistically significantly higher subgroup training more than eight hours compared to study subgroup training less than eight hours (p=0.01) (Table 3).

When the study group participants were assessed according to sports type classification; there were 5 participants in green, 7 in blue, 56 in yellow, 15 in orange and 43 in red area. Any statistically significant differences regarding echocardiographic parameters were not determined between these subgroups (p>0.05).

Table 3. Echocardiographic measurements of groups according to training hours per week

	Control group (n=62)	Less than 8 hours a week	More than 8 hours a week
AR mm	21.5±2.6	22.1±3.4	24.0±3.5
AA mm	20.3±2.1	21.0±2.9	21.7±2.4
LAD mm	25.2±3.4	26.8±3.8	29.0±4.4
EF %	71.2±6.2	71.8±5.3	71.9±6.5
FS%	40.5±5.2	41.1±4.5	41.7±5.8
LVEDd mm	42.8±4.0	43.3±5.5	43.4±6.8
LVESd mm	25.1±3.9	25.2±4.4	25.5±4.6
IVSD mm	9.2±2.1	10.3±2.3	10.8±2.1
IVSS mm	12.1±2.1	13.3±2.5	14.3±2.5
LPWd mm	7.8±1.7	9.3±1.9	10.5±2.8
LPWs mm	13.3±3.7	15.2±2.7	15.7±3.9
Mitral E/A	1.6±0.2	1.9±0.2	1.9±0.2

AR: Aortic root; AA: Asendan aorta; LAD: Left atrial diameter; EF: Ejection fraction; FS: Shortening fraction; LVEDd: Left ventricle end diastolic diameter; LVESd: Left ventricle end sistolic diameter; IVSD: Interventriculer septum in diastole; IVSS: Interventriculer septum in systole; LPWD: Left ventricle posterior wall thickness in diastole; LPWs: Left ventricle posterior wall thickness in systole.

DISCUSSION

The adaptation of heart to training has been largely studied in adults currently. However, there is still limited data about adaptation of children's heart to training which is still in maturation period. In this study we determined that regular exercise training induces cardiovascular changes in children. Firstly in the present study, heart rate was determined to be statistically significantly lower in study group. It is a well-known fact that long term endurance training is associated with cardiac neural remodeling in the favor of cardio-protective vagal mechanisms, resulting in resting bradycardia [9]. Different pediatric and adult studies showed that athletes were having significantly greater prevalence of sinus bradycardia compared with the non-athletes [5, 10]. Similarly, Sharma et al. evaluated the electrocardiographic alterations in 1000 junior athletes with a mean age of 15.7 years and reported that athletes had a significantly higher prevalence of sinus bradycardia and sinus arrhythmia than non-athletes with significantly prolonged PR interval, QRS and QT durations [11]. Although we did not evaluate the electrocardiographic changes; we also determined that regular training in children is associated with lower heart rates. We believe that this alteration is associated with the increased vagal tone and increased cardiac size as reported in previous studies [11].

Cardiac output increases up to 30 L/min to 40 L/min with a positive linear relationship to intensity of activity during exercise in trained subjects [12]. However, it may eventually lead to increased hemodynamic insult and mechanical stress on the great vascular structures and cardiac chambers. Associated with increased blood flow, hemodynamic insult or increased shear stress during exercise, dilatation of aortic root and ascending aorta could be observed due to medial degeneration of vessel layer [12]. Ventricular systolic ejection fraction was also determined to be increased in training children [6]. Secondly, in the present study the echocardiographic measurements of aortic dimensions; AR and AA were significantly higher in study group (p=0.02, p=0.03 respectively). Similarly, it was reported recently that aortic dilation and subsequently, thoracic aorta aneurysms may be an occupational disease due to the nature of some professions including athletes [13]. The compensation procedure for this elevated cardiac output and overload of the flowing blood results in increase of not only the diameter of aorta but also diameter of cardiac chambers and relative wall thickness [14, 15].

Thirdly, in the present study, LVPWd, LVPWs, IVSd, IVSs were statistically significantly higher in study group while there were no differences in LVEDd and LVESd measurements. However, an increase in the left ventricular end-diastolic diameter associated with an improvement in diastolic function after training compared with the resting data was reported previously [16]. Two main types of athlete's heart were described according to the type of exercise as dynamic or static. Eccentric hypertrophy (increase in cavity diameter and wall thickness), concentric hypertrophy (increase in wall diameter without any change on cavity size) and heterogeneity with respect to involvement of sports both static and dynamic cardiovascular demands [17]. Therefore, individuals with athlete's heart could exhibit further cardiac adaptation in response to different trainings [18, 19]. In that aspect in evaluation of different results reported in literature about the effects of training on cardiac functions; the type of training should be considered.

Our findings are due to heterogeneity of study group and also support further cardiac adaptation according to sports type. Similarly, Venkunas T et al did not observe any significant differences in the end diastolic diameter between athletic and control groups [20].

Fourthly, one of the significant findings to be discussed was greater LAD measurement in study group compared with the control group. The increase of the left atrium is common in athletes due to increased pressure in the cavity during exercise. Toufan et al recently reported that left atrium diameters were increased as a left atrial remodelling in response to prolonged duration of regular endurance sports [19].

Fifthly, regarding the diastolic function, there was a significant increase of the E/A Ratio in study group. In several studies related to diastolic function in athletes, an increase in E-wave velocity and an increase in the E/A Ratio have been observed from different sports [20, 21]. These findings are suggestive of a supernormal diastolic function mediated by a combination of improved initial ventricular relaxation and increased left ventricular compliance.

When the study group was examined in itself according to training hours, statistically significant increases in LVPWd, LA and AR were detected in participants training over 8 hours per week. Similarly, a study in which participants were divided into groups according to training hours per week reported that interventricular septum thickness, end-diastolic diameter and left ventricular mass were significantly higher in athletes whose training exceeded 8 hours per week compared to the controls [22]. Agrebi et al reported that among children who were having a regular training for handball, LVEDD, LVESd, LA, AR and LV mass were all significantly lower in younger children compared with the older ones and adults [23]. This finding was suggested to be associated with the duration of prior practice and early cardiac remodeling. We did not subgroup the patients regarding their ages but this data also supports our finding that with an increase in training time, LVEDd, LVESd, LA, AR and LV mass were increasing.

It is a well-known fact that cardiovascular response to sports is associated with the type and duration of exercise [24, 25]. Since, our study group was so heterogeneous when classified according to sports type, no difference could be determined between groups regarding echocardiographic parameters.

We did not determine any significant alterations in systolic blood pressure between study and control groups. In a recent study, Tan et al. [26] reported a decrease in both systolic blood pressure and heart rate of obese children with exercise training. We did not determine body mass indices of children in this study; which may be the topic of future investigations.

There are some limitations of this study that should be defined. First is the low number of study participants and second is the assessment of only short-term records. Moreover, in a recent study, D'Ascenzi et al determined an increase in right ventricle size after 5 months of intensive training in children without an alteration in its functions that was suggested as a part of remodelling period [27].

Conclusion

The principal aspect of present study is confirmation of presence sport related cardiovascular changes in children similar to adults.

These parameters were mostly dependent on the duration of training hours per week.

Further prospective, larger, long term follow-up studies are warranted to understand the importance of especially sports type on cardiovascular response.

Conflict of Interest: The authors declare no conflict of interest.

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