KAUNAS UNIVERSITY OF MEDICINE

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THE IMPACT OF PHYSICAL LOAD ON LEFT VENTRICULAR MORPHOMETRIC PARAMETERS AND FUNCTION OF THE CARDIOVASCULAR SYSTEM IN CHILDREN AND ADOLESCENTS ATHLETES

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KAUNO MEDICINOS UNIVERSITETAS

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FIZINIO KRŪVIO POVEIKIS SPORTUOJANČIŲ VAIKŲ IR PAAUGLIŲ KAIRIOJO SKILVELIO MORFOMETRINIAMS RODIKLIAMS BEI ŠIRDIES IR KRAUJAGYSLIŲ SISTEMOS FUNKCIJAI

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ABBREVIATIONS

A	–	peak late transmitral flow velocity
B	–	basketball players
BMI	–	body mass index
BP	–	blood pressure
BSA	–	body surface area
C	–	cyclists
DBP	–	diastolic blood pressure
E	–	peak early transmitral flow velocity
E/A	–	ratio of E to A
ECG	–	electrocardiogram
ES	–	executive system
f	–	speed of changes in functional parameter during workload
F	–	Fisher criterion
FS	–	shortening fraction
HR	–	heart rate
IVSTd	–	interventricular septal thickness at end diastole
IVSTd/BSA$^{1/2}$	–	interventricular septal thickness at end diastole inde-xed to body surface area raised to the power of 1/2
JT	–	time interval on electrocardiogram from the J point to the end of T wave (JT interval)
JT/RR	–	relative repolarization
LV	–	left ventricle
LVIDd	–	left ventricular internal diameter at end diastole
LVIDd/BSA	–	left ventricular internal end-diastolic diameter index
LVIDd/BSA$^{1/2}$	–	left ventricular internal diameter at end diastole indexed to body surface area raised to the power of 1/2
LVIDd/height$^{2.7}$	–	left ventricular internal diameter at end diastole indexed to height raised to the power of 2.7
LVIDs	–	left ventricular internal diameter at end systole
LVM	–	left ventricular mass
LVMI	–	left ventricular mass index
LVM/BSA$^{3.2}$	–	left ventricular mass indexed to body surface area raised to the power of 3.2

LVPWTd	–	left ventricular posterior wall thickness at end diastole
LVPWTd/BSA$^{1/2}$	–	left ventricular posterior wall thickness at end diastole indexed to body surface area raised to the power of 1/2
N	–	non-athletes (control subjects)
R	–	rowers
RR	–	time elapsing between two R waves (interval RR)
RS	–	regulatory system
SS	–	supplying system
RWT	–	relative wall thickness
SBP	–	systolic blood pressure
(SBP–DBP)	–	difference between systolic and diastolic blood pressure, pulse pressure
SD	–	standard deviation

INTRODUCTION

Good health of a child is associated with physical activity. Accumulating scientific evidence indicates the importance of physical activity not only to healthy child lifestyle, but also to the prevention of various childhood-onset chronic diseases [Luepker et al., 1995, Torrents et al., 2006].

Discussing issues of physical activity in children, physical education should be distinguished from regular, long-term, intensive professional sports, striving for professional sporting achievements. During the adaptation to physical load of such pattern, the body undergoes complex interrelated structural and functional changes of many organ systems [Biggiero, 2001]. The adaptation of the human body to regular long-term physical training has been the focus of continuous scientific research to date. Despite this, many questions remain unanswered especially in analyzing the impact of long-term physical load on the body of children and adolescents.

The role of the cardiovascular system is crucial in the processes of adaptation to long-term exercise training. The impact of physical exercise on cardiovascular system in adult athletes is well recognized [Fagard, 1997; Pluim et al., 2000; Pelliccia, et al., 2002; Fagard, 2003]. The popularity of different types of sports is increasing; younger children are being engaged in sports, but data regarding the impact of physical load on their body are limited. As a child grows, his/her cardiovascular system undergoes constant changes: an increase in cardiac size and weight and changes in functional indices are observed. During puberty, ongoing changes in the body, especially hormonal, have an impact on the cardiovascular system. Consequently, cardiovascular system in athletic children and adolescents is influenced not only by physical load, but also by rapid body growth and maturation [Rowland, 1994; Pavlik, 1996; Pavlik 2001; Bar-Or, 2004]. These factors should be considered in the evaluation of the impact of long-term physical load on left ventricular morphometric parameters and function in children and adolescents.

Long-term physical load is associated with remodeling of cardiac geometry referred as physiological left ventricular hypertrophy or ‘athlete’s heart’ [Fagard, 2003; Pluim et al., 2000]. This physiological form of hypertrophy – the athlete’s heart – is accepted as a favorable result of adaptation to regular (systemic) physical training. The differentiation between physiological left ventricular hypertrophy, characteristic of athlete’s heart, and pathological forms of hypertrophy – hypertrophic and dilated cardiomyopathy – causing sudden death in the athletic population, is crucial. Previous echocardiographic studies of adult athletes have defined upper limits of echocardiographic indices characteristic of physiological left ventricular hypertrophy; therefore, if indices exceed the upper limits, hypertrophic or dilated cardiomyopathy can be suspected. However, these criteria are not applicable in children. Data in the scientific literature regarding reference values for acceptable upper limits of left ventricular hypertrophy indices in child and adolescent athletes are scarce [Makan et al., 2005; Sharma et al., 1999].

Many studies have showed an impact of age, anthropometric data, sporting discipline, training duration and volume, systolic blood pressure at rest and at peak exercise on left ventricular morphometric parameters and functional indices of the cardiovascular system in adult athletes [Fagard, 1997; Pavlic et al., 2001; Karjalainen et al., 1997; Puffer, 2002]. However, in Lithuania and over the world, there is a lack of studies examining the impact of these factors on the changes in left ventricular morphometric parameters in children and adolescents engaged in sports.

Functional capacity of the cardiovascular system determines adaptation of the organism to long-term physical load. On the other hand, functional capacity of the cardiovascular system often becomes a factor limiting adaptive processes in the body [Thomson, 2000]. During intensive and regular exercise training, limits of physiological changes can be exceeded, and this might result in health- and life-threatening situations. Therefore, it is of crucial importance for physicians to evaluate precisely adaptive changes of the cardiovascular system and differentiate them from pathological conditions in child and adolescent athletes.

During physical load, not only cardiovascular system is activated, but also complex changes take place in the whole body. Therefore, with the aim to evaluate the functions of various systems, interrelation between them and systemic response of the body to physical load, a complex research on distinctive features of not only functional indices of the cardiovascular system, but also parameters reflecting interrelationship among functional systems of the body and speed of their changes is carried out. The goal of such complex research is the evaluation of adaptive and reserve capabilities of the athlete's body and individualization and optimization of physical load.

In Lithuania, systemic adaptation of the body to physical load in adult athletes has become the subject of extensive research [Vainoras, 1996;

Poderys, 2004; Žumbakytė, 2007]. However, both in Lithuanian and worldwide literature, there is a paucity of scientific studies examining functional state of the cardiovascular system and systemic response of the body to physical load in athletic children and adolescents. Furthermore, in everyday medicine practice, both sports medicine specialists and pediatricians encounter deadaptation of the body of athletic children and adolescents, and assessment of these above-mentioned phenomena has been limited by the lack of methods.

With newly emerging sports, raising numbers of children and adolescents engaged in sports and their striving for outstanding sporting achievements at any price, clinical specialists experience the increasing demand of knowledge to understand distinctive features of the cardiovascular system in athletic children and adolescents in order to evaluate correctly and timely the limits of physiological changes and functional capabilities, individualize and optimize physical load.

The aim of the study

To evaluate the impact of long-term physical load on changes in left ventricular morphometric and cardiovascular functional parameters, to analyze their relationship and to identify the factors influencing left ventricular morphometric parameters in child and adolescent athletes.

The objectives of the study

1. To compare left ventricular echocardiographic parameters between child and adolescent athletes and non-athletes;
2. To determine the impact of age, height, weight, body surface area, type of sporting discipline, training duration and training volume, systolic blood pressure at rest and at peak exercise on left ventricular echocardiographic parameters in child and adolescent athletes;
3. To evaluate left ventricular geometry and to determine the factors influencing LV geometry in child and adolescent athletes;
4. To evaluate the possibility of predicting cutoff values for interventricular septal thickness and left ventricular internal diameter at end diastole in athletic children and adolescents;
5. To assess cardiovascular functional parameters and speed of their changes in child and adolescent athletes;
6. To identify the relationship between cardiovascular functional and echocardiographic parameters in child and adolescent athletes.

Scientific novelty and significance of the study. In Lithuania, as in the rest of the world, there is a lack of studies that would allow an adequate evaluation of the adaptation of the cardiovascular system to long-term physical load in child and adolescent athletes and would analyze the differences in echocardiographic and functional parameters of the cardiovascular system between athletes and non-athletes. In the everyday practice of sports medicine, evaluation of characteristic features of physiological left ventricular hypertrophy in children engaged in sports activities, differentiation between physiological left ventricular hypertrophy and pathological forms of cardiac hypertrophy, which might result in sudden death in athletes, and timely diagnosis of threshold functional capabilities, exceeding which deadaptive phenomena might occur, are limited by the lack of methods. The first comprehensive data on distinctive features of echocardiographic parameters and functional indices of the cardiovascular system in the population of 12–17-year-old athletes have been gathered in Lithuania. The factors that might have an influence on left ventricular echocardiographic parameters in athletes have been identified. For the first time in Lithuania, cutoff values for echocardiographic parameters, allowing the differentiation between physiological left ventricular hypertrophy and cardiomyopathy, have been predicted. Literature data show that no similar studies have been performed to date, where having applied the evaluation model for functional state of the human body and having analyzed functional parameters and speed of their changes, adaptation of the cardiovascular system and the whole body to long-term physical load in 12–17-year-old children and adolescents has been assessed using a complex evaluation. For the first time, associations between left ventricular echocardiographic and functional parameters and speed of their changes were determined in Lithuania. Findings from this study permit more precise recommendations regarding individualization and optimization of physical load in children and adolescents engaged in sports, based on the analysis of speed on changes in functional indices of the cardiovascular system, and accurate assessment of data obtained on echocardiography and cycle ergometer testing.

1. STUDY POPULATION AND METHODS

Study population

The study was carried out in Klaipėda Children's Hospital, Klaipėda Medical Centre "Salvija" and Klaipėda Sports Medicine Centre between December 2007 and February 2009. The study protocol was approved by the Kaunas Regional Ethics Committee for Biomedical Research (protocol No. 151/2007).

Athletes living in Klaipėda and using health care services at Klaipėda Sports Medicine Centre were invited to participate in the study, when they arrived for routine physical examination. Study participants belonged to various regional teams; 15 (8.9%) athletes were members of the national team. After matching the inclusion criteria, 167 (87.9%) 12–17-year-old male athletes agreed to be enrolled into the study: 62 (37.2%) basketball players, 51 (30.5%) rowers (academic rowing) and 54 (32.3%) cyclists.

Inclusion criteria:

1. Age 12 to 17 years;
2. Male gender;
3. Training duration of a minimum of one year;
4. Type of sporting disciplines (basketball, rowing, cycling);
5. Training volume – involvement in training not less than 3 hours per week outside of physical education classes in school during the last years.

Exclusion criteria:

1. Trauma experienced during the last 3 months before the study and during it;
2. Long-term use of medications (anabolic steroids, beta-blockers);
3. Acute diseases acquired one month before the study and during it.

Control group

The control group comprised 168 pupils from Klaipėda secondary school selected considering age and sex (matched control group). Therefore, control subjects were matched to athletes.

*Inclusion criteria***:**

1. Age 12–17 years;
2. Male gender;
3. Any involvement in additional sports activities outside of physical education classes in school during the last years;
4. Good physical health confirmed by a health certificate issued by a general practice physician.

Through the study, at a time convenient to the participants, three visits were organized on different days. Before the beginning of the study, during the first visit to Klaipėda Children's Hospital, the participants and their parents were given by the author verbal and written instructions about the objectives, methods, risks and benefits of this study. Study participants who agreed to participate in the study and their parents signed written consent form. The weight and height of all study participants were recorded and echocardiography was performed by the author of this study. During the second visit a cycle ergometer test was performed in study athletes. During the third visit, control subjects performed the cycle ergometer test.

Study methods

Anthropometric measurements. Height was measured with a SECA stadiometer. Weight was determined using a mechanical medical scale SECA. Weight was measured with an accuracy of 0.1 kg. Body surface area (BSA) was calculated by applying the standard formula [50]:

$$\text{BSA (m}^2\text{)=(height (cm))}^{0.725}\times\text{(body weight (kg))}^{0.425}\times 0.007184$$

Echocardiography. Standard two-dimensional transthoracic echocardiograms were recorded using a Philips sonograph with a 3.5 MHz transducer, in the left lateral decubitus position. Echocardiographic studies were carried out by the main investigator (A.B.) having a license of pediatric cardiologist. Three consecutive measures of every parameter were made and the average was taken by the investigator. All measurements were performed according to the recommendations of the American College of Cardiology and the American Society of Echocardiography [Cheitlin et al., 1997]. Two-dimensionally targeted M-mode images in the pasternal long axis at the tips of the mitral valve leaftlets were used to measure the following echocardiographic parameters at end diastole: interventricular septal thickness at diastole and systole, left ventricular internal diameter at end diastole, left ventricular internal diameter at end systole and left ventricular posterior wall thickness.

Left ventricular diastolic function was evaluated measuring mitral flow. Mitral flow velocities were recorded from the apical four-chamber view by placing a 1- to 2-mm sample volume between the tips of the mitral leaflets during diastole. From the mitral flow velocity tracings, peak early transmitral flow velocity (E, m/s) and peak late transmitral flow velocity (A, m/s) were measured, and the ratio of early to late diastolic filling (E/A) was calculated.

Left ventricular systolic function was evaluated by examination of fractional shortening, which was calculated using the following formula [Cheitlin et al., 1997]:

$$FS\ (\%)=\{(LVIDd - LVIDs)/LVIDd\}\times 100,$$

where LVIDd indicates left ventricular internal diameter at end diastole; and LVIDs, left ventricular internal diameter at end systole.

Left ventricular mass (LVM) was calculated by applying the modified Devereux formula accepted by the Penn Convention (Devereux et al.):

$$LVM=0.8\times[1.04\ \{(LVIDd+LVPWTd+IVSTd)^3 - LVIDd^3\}]+0.6\ g,$$

where LVM indicates left ventricular mass; IVSTd, interventricular septal thickness at end diastole; PWTd, left ventricular posterior wall thickness at end diastole; LVIDd, left ventricular internal diameter at end diastole; 1.04, density of myocardial tissue; 0.8, correction factor.

Left ventricular mass index (LVMI) was calculated using the following formula [Devereux et al., 1986]:

$$LVMI=LVM/BSA\ (g/m^2),$$

where LVMI indicates left ventricular mass index; LVM, left ventricular mass; BSA, body surface area (m^2).

Relative left ventricular wall thickness was calculated using the following formula:

$$RWT=(IVSTd+LVPWTd)/LVIDd,$$

where IVSTd indicates interventricular septal thickness at end diastole; LVPWTd, left ventricular posterior wall thickness at end diastole; LVIDd, left ventricular internal diameter at end diastole.

Aiming to compare echocardiographic parameters among study subjects of different age and anthropometric data, not only absolute but also relative echocardiographic parameters, related to body surface area and height, were calculated. LV internal end-diastolic diameter index (LVIDd/BSA) was calculated by dividing LV internal diameter at end-diastole by body surface area. Echocardiographic parameters indexed to height – LV internal diameter at end diastole and LV mass – were calculated by dividing LVIDd and LVM by height, raised to the power of 2.7. In addition, calculations were performed based on methodology suggested by Pavlic et al.: interventricular septal thickness at end diastole, LV posterior wall thickness and LV internal diameter at end diastole, expressed in mm, were divided by body surface area, raised to the power of 1/2, and LVM, expressed in g, was divided by body surface area, raised to the power of 3/2 [Pavlik et al., 1996; Petridis et al, 2004].

Cycle ergometer test. The participants completed cycle ergometer test on an ergometer by performing two-minute cycling bouts at incrementally ascending workloads to submaximal HR (85% of maximal heart rate) or symptom-limited maximum [Gibbons et al.; 1997].

For bicycle ergometer testing, the McMaster protocol was used: if a subject was shorter than 160 cm, the initial workload of 25 W was applied further increasing it by 25 W every 2 minutes; if a subjects was taller than 160 cm, the initial workload of 25 W was applied further increasing it by 50 W every 2 minutes [Bar-Or, 2004; Washington et al., 1994]. The pedaling frequency was maintained at 60 revolutions per minute throughout testing.

During cycle ergometer testing, at rest and during the last 10 s of every step of physical load, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using an aneroid manometer, and 12-lead ECG was recorded. Blood pressure (BP) at rest was measured three times every two minutes in the sitting position by auscultation of Korotkoff's sounds over the brachial artery using a stethoscope. In the evaluation of BP, a mean value of three measurements was obtained. After measuring BP, pulse pressure (SBP–DBP) was calculated at rest and during every step of physical load. During 12-lead echocardiography, heart rate and JT interval were measured at rest and during every step of physical load; RR interval and relative JT/RR index were calculated.

During cycle ergometer testing, parameters reflecting several main interrelated systems of the human body – executive (ES), supplying (SS) and regulatory (RS) – were registered. By using the model of integral response of the human body to physical load, both separate and integrated functions of the systems mentioned above were evaluated [Vainoras, 1996; Žumbakytė, 2007]. With the aim to evaluate the relationship among separate systems at rest and during every step of physical load, a relative index – JT/RR – was calculated.

Functional parameters SBP and HR are more associated with regulatory system, SBP–DBP is associated with function of peripheral muscles and describes the response of executive system; JT interval describes supplying system and JT/RR reflects associations between regulatory and supplying systems.

With the aim to evaluate a quantitative value of change in functional parameters (HR, JT, JT/RR, SBP, DBP, (SBP–DBP) during physical load, speed of changes in functional parameters was calculated every second minute, i.e. it was determined how much functional indices were increased for one watt of load every second minute of physical load.

Speed was calculated according to the formula:

$$f_i = (f(N_{i+2}) - f(N_i))/(N_{i+2} - N_i),$$

where f_i indicates speed of changes in a functional parameter during physical load; f, numerical value of functional parameter; i = 2, 4, 6, 8, 10, the second, fourth, …, minute of physical load, when load is increased every 2 min; N = 0, 25, 50, 75, 100, 125, 150, 175 W for study participants who were shorter than 160 cm and N = 0, 25, 75, 125, 175, 225, 275 W for study participants who were taller than 160 cm.

Speed of changes in parameters was defined as follows:

JT2 – speed of changes in JT parameter from 0 W to 25 W for all the study participants.

JT4 – speed of changes in JT parameter from 25 W to 50 W for the study participants who were shorter than 160 cm and from 25 W to 75 W for the study participants who were taller than 160 cm at the fourth minute of workload.

JT6 – speed of changes in JT parameter from 50 W to 75 W for the study participants who were shorter than 160 cm and from 75 W to 125 W for the study participants who were taller than 160 cm at the sixth minute of workload.

JT8 – speed of changes in JT parameter from 75 W to 100 W for the study participants who were shorter than 160 cm and from 125 W to 175 W for the study participants who were taller than 160 cm at the eighth minute of workload.

JT10 – speed of changes in JT parameter from 175 W to 225 W for the study participants who were taller than 160 cm at the 10th minute of workload.

Indications of speeds of changes for other parameters – HR, JT/RR, SBP, SBP–DBP – were analogous.

Statistical analysis. Standard statistical parameters were applied for the descriptive analysis: for continuous data – arithmetic mean, 95% confidence interval (CI), standard deviation, dispersion and median; for nominal data – distribution proportions (95% CI). For testing statistical hypotheses, parametric tests (paired or unpaired *t* test, ANOVA, linear regression and Pearson linear correlation coefficient) were used with the assumption that the data being tested were normally distributed, and for testing statistical significance in small size samples, nonparametric tests were applied (Mann-Whitney). Kruskal-Wallis test was used for comparison of three groups or more; Spearman rank correlation was used to determine the covariance between two nominal variables. Statistical significance was examined by chi-square (χ^2) test, Fisher exact test.

The relationship of age, antropometric data, sporting discipline, training volume and training duration, systolic blood pressure at rest and during maximal load to the echocardiographic parameters of LV of participants was analysed using univariate and multivariate stepwise regression techniques. At the beginning, we indentified parameters related to echocardiographic parameters of LV of participants. Using the determination coefficient R^2 value and the model correspondence criterion, we created the optimal regression model allowing for prognosis of echocardiographic parameters of participants. Factors that were not statistically significant and worsened the R^2 value were excluded from the final regression model.

Predicted limits of echocardiographic parameters (IVSTd, LVIDd) were calculated based on the mean IVSTd and LVIDd values +2 SD for the control subjects for every year of age.

Reference limits for the analysis of left ventricular geometry were calculated using the 95th percentile of relative wall thickness and mass index for control subjects. Normal LV geometry was defined when the mean values of LVMI and RWT were below the 95th percentile; concentric LF remodeling, when LVMI was below and RWT above; LV concentric hypertrophy, when LVMI and RWT were above; and eccentric LV hypertrophy, when LVMI above and RWT below the 95th percentile [Matteucci, 2006; Foppa, 2005]. Stepwise logistic regression was used to determine the independent factors determining IVSTd and LVIDd values exceeding predicted limits and abnormal LV hypertrophy, expressed as odds ratio and 95% CI. All statistical analyses were performed using SPSS for Windows 15.0 software. A 2-tailed value of $p<0.05$ was considered statistically significant.

2. RESULTS

2.1. General demographic, anthropometric and training characteristics of athletes and controls

A total of 167 athletes with a mean age of 14.8±1.6 years and 168 nonathletic controls with a mean age of 14.6±1.4 were enrolled into the study. There were no significant age, height, weight, BSA and body mass index (BMI) differences between athletes and controls (Table 2.1.1).

Table 2.1.1. *Comparison of demographic, anthropometric and training parameters between athletes and controls*

Characteristic	**Athletes, n=167**		**Controls, n =168**		**p value**
	Mean (SD)	**95% CI**	**Mean (SD)**	**95% CI**	
Age, years	14.8 (1.6)	14.6–15.1	14.6 (1.4)	14.6–15.0	0.923
Height, cm	175.9 (10.4)	174.3–177.5	174.3 (10.3)	172.7–175.8	0.103
Weight, kg	63.9 (13.5)	61.9–65.9	63.3 (15.6)	61.4–65.3	0.696
BSA, m^2	1.76 (0.23)	1.72–1.79	1.73 (0.19)	1.71–1.76	0.282
BMI, kg/m^2	20.4 (2.8)	20.0–20.9	20.5 (2.3)	20.1–20.9	0.758
Training, yr	3.2 (2.2)	2.9–3.6	–	–	–
Training, h/wk	8.1 (2.3)	2.6–2.9		–	–

BSA, body surface area; BMI, body mass index; SD, standard deviation.

There were no differences in anthropometric data between the athletes involved in different sporting discipline and controls except for the height, which was higher in basketball players than controls and BSA which was greater in cyclists than that of basketball players and rowers. Training duration of basketball players was longer than of rowers and cyclists, and rowers were engaged in more extensive training than basketball players (Table 2.1.2).

Table 2.1.2. *Comparison of demographic, anthropometric and training data among athletes involved in different sporting discipline*

Characteristic	**Basketball players, n=62**	**Rowers, n=51**	**Cyclists, n=54**	**Controls, n=168**	**p<0.05**
	B	**R**	**C**	**N**	
Age, yr	14.9 (1.4)	14.9 (1.7)	14.7 (7.4)	14.8 (1.6)	–
Training, yr	4.3 (1.9)	2.4 (1.4)	2.7 (1.4)	–	B>R,C
Training, h/wk	8.1 (2.3)	11.2 (5.5)	9.7 (3.2)	–	R>B
Height, cm	178.7 (11.4)	176.9 (8.5)	172.1 (9.8)	174.3 (10.3)	B>C,N
Weight, kg	66.7 (14.5)	65.6 (12.5)	59.2 (12.1)	63.4 (13.1)	B>C
BSA, m^2	1.81 (0.24)	1.78 (0.21)	1.67 (0.22)	1.73 (0.19)	C<B,R

Data are expressed as mean (SD, standard deviation); BSA, body surface area.

2.2. Echocardiographic parameters in athletes and controls

The findings of the study showed that all absolute echocardiographic parameters and parameters indexed to body surface area and height were significantly greater than analogous parameters in the control group, except for LVIDd indexed to height (LVIDd/height$^{2.7}$). There was a greater percentage difference in IVSTd and LVPWTd than in LVIDd athletes and control subjects (14.3%, $p<0.001$ and 14.2%, $p<0.001$ versus 5.4%, $p<0.001$ and 4.1%, $p<0.001$). This difference remained even after indexation of parameters to body surface area (Table 2.2.1).

Table 2.2.1. *Comparison of echocardiographic parameters between athletes and controls*

Parameter	Athletes, n=167		Controls, n=168		Δ, %[1]	p value
	Mean	**95% CI**	**Mean**	**95% CI**		
LVIDd, mm range, mm	50.16 42–63	49.56–50.77	47.59 38–54	47.15–48.03	5.4	<0.001
IVSTd, mm range, mm	9.67 6–13.8	9.46–9.88	8.41 6–11	8.25–8.58	14.3	<0.001
LVPWTd, mm range, mm	9.21 6–13	9.00–9.42	8.06 6–10.8	7.90–8.23	14.2	<0.001
RWT	0.38	0.37–0.38	0.35	0.34–0.35	8.5	<0.001
LVM, g	173.28	166.6–180.20	130.98	126.6–135.4	32.3	<0.001
LVMI, g/m^2	97.70	94.73–100.66	75.06	73.25–76.87	30.7	<0.001
FS, %	38.53	38.07–38.99	37.69	37.82–38.41	2.2	0.028[a]
E, m/s	1.01	0.99–1.03	0.91	0.89–0.97	10.9	<0.001[a]
A, m/s	0.52	0.50–0.53	0.49	0.48–0.50	6.1	0.001[a]
E/A	1.99	1.94–2.05	1.89	1.84–1.93	5.2	0.003[a]
IVSTd/$BSA^{1/2}$, mm/m	7.31	7.18–7.44	6.39	6.28–6.49	12.5	<0.001
LVPWTd/ $BSA^{1/2}$ mm/m	6.96	6.83–7.10	6.13	6.02–6.23	11.9	<0.001
LVIDd/$BSA^{1/2}$, mm/m	37.99	37.64–38.36	36.22	35.95–36.50	4.7	<0.001
LVM/$BSA^{3/2}$, g/m^3	73.83	71.68–75.99	57.09	55.77–58.42	29.4	<0.001
LVM/$height^{2.7}$, $g/m^{2.7}$	37.36	36.18–38.53	29.04	28.29–29.79	22.2	<0.001
LVIDd/$height^{2.7}$, $mm/m^{2.7}$	11.05	10.83–11.28	10.7	10.51–10.96	3.7	0.051
LVIDd/BSA, mm/m^2	28.9	28.4–29.3	27.7	27.3–28.0	4.1	<0.001

CI, confidence interval; [1] Δ%, difference between athletes and controls; [a] nonparametric Mann-Whitney test.

2.2.1. Factors influencing left ventricular echocardiographic parameters in athletes and controls

In univariate linear regression analysis, the associations between anthropometric data and LVM in the athletes and control subjects were determined. Age was the most significant univariate prognostic factor for LVM in the athletes (R^2=0.581, p<0.001), and in the control subjects – body weight (R^2=0.559, p<0.001).

A moderate and strong correlation was found among LVM and age, height, body weight and body surface area of athletes. In athletes, LVM had the strongest correlation with age (r=0.76, p<0.001) and consequently high correlations with body weight, height and BSA, but there were no significant correlations to sporting discipline. Sporting discipline had an impact on LVPWTd (F=3.74 p=0.026), RWT (F=7.85 p=0.001), E/A (F=5.18 p=0.007) and all LV echocardiographic parameters indexed to body surface area except for IVSTd/BSA$^{1/2}$. Correlation between LVM and functional parameters athletes – HR and SBP at rest and SBP during the maximal physical load – was determined. LVM of athletes was correlated with SBP at rest (r=0.31, p<0.01), but with heavier exercise loads this association strengthened, being maximal during maximal load (r=0.68, p<0.001). In addition, relationship of training duration and training volume with LVM in the athletes was determined. LVM correlated with training volume more closely (r=0.43, p<0.01) comparing to correlation among LVM and training duration (r=0.25, p<0.01). In univariate analysis, LVM of control subjects had the strongest correlations with body weight (r=0.75, p<0.01) and strong correlations with age, height and BSA, SBP during maximal load, but was not associated with HR and SBP at rest (Table 2.2.1.1).

Table 2.2.1.1. *Pearson correlation coefficient (r) between left ventricular mass and age, anthropometric data, training duration, training volume and blood pressures at rest and during maximal load*

Parameter	**Correlation (r) with LVM (g)**	
	Athletes, n=167	**Controls, n=168**
Age, yr	0.76 **	0.65 **
Weight, kg	0.68 **	0.75 **
Height, cm	0.63 **	0,62**
Body surface area, m^2	0.69 **	0.60 **
Training, years	0.25*	–
Training, h/wk	0.43*	–
Heart rate, bpm	–0.42*	–0.22
Systolic blood pressure at rest, mm/Hg	0.31*	0.17
Systolic blood pressure during maximal load, mm/Hg	0.68 **	0.49**

**p<0.001; *p<0.01

In multiple linear regression analysis, only age and body weight were independent factors of LVM in athletes. In the athletes, LVIDd and IVSTd were dependent on training volume, LVIDd – on sporting discipline and LVPWTd – on BSA. Training duration, SBP at rest and during maximal load had no significant influence on LV echocardiographic parameters in athletes. All echocardiographic parameters of participants in the control group (LVM, IVSTd, LVIDd, LVPWTd) were dependent on age and BSA (Table 2.2.1.2).

Table 2.2.1.2. Factors influencing left ventricular echocardiographic parameters in athletes (multiple linear regression)

Parameter (dependent variable)	Model	Coefficients of regression			p	Model R^2, %
		B	SE *B*	Beta		
LVM, g	(Constant)	–126.505	19.87		<0.001	R^2=63.6
	Age, yr	15.478	1.71	0.550	<0.001	
	Weight, kg	1.101	0.20	0.328	<0.001	
LVPWTd, mm	(Constant)	1.733	0.77		0.026	R^2=41.3
	Age, yr	0.399	0.07	0.466	<0.001	
	BSA, kg/m^2	1.523	0.48	0.257	0.002	
IVSTd, mm	(Constant)	0.728	0.78		0.350	R^2=50.6
	Age, yr	0.443	0.06	0.521	<0.001	
	Training, h/wk	0.049	0.02	0.142	0.028	
LVIDd, mm	(Constant)	25.879	2.04		<0.001	R^2=53.5
	Age, yr	1.095	0.18	0.458	<0.001	
	Weight, kg	0.124	0.02	0.433	<0.001	
	Sport (discipline)	0.612	0.17	0.201	<0.001	
	Training, h/wk	–0.123	0.06	–0.128	0.045	

Adjusted for age, height, weight, body surface area, training volume, training duration, sporting discipline, SBP at rest, SBP at peak exercise and age* training duration; R^2-corrected coefficient of determination; B-coefficient of regression equation; β-standardised coefficient of linear regression; SE-standard error; HR-heart rate; SBP-systolic blood pressure.

LVM of basketball players was dependent on age, body weight and training duration. Age and training duration were independent factors for LVM in cyclists, and age – in rowers. LVPWTd in basketball players and IVSTd in cyclists were associated with training duration.

2.2.2. Comparison of echocardiographic parameters in athletes representing different sporting disciplines

All absolute echocardiographic parameters and echocardiographic parameters indexed to body surface area (LVIDd, IVSTd, LVPWTd, RWT, LVM, LVMI, IVSTd/BSA$^{1/2}$, LVPWTd/BSA$^{1/2}$, LVIDd/BSA$^{1/2}$, LVM/BSA$^{3/2}$) were higher in basketball players, rowers and cyclists than analogous parameters in the control group, except for LVIDd indexed to BSA. Only cyclists had a greater LVIDd/BSA than did control subjects ($p<0.05$) (Table 2.2.2.1).

Table 2.2.2.1. *Comparison of echocardiographic parameters between athletes and controls. Data are means (SD)*

Parameter	Basketball players, n=62	Rowers, n=51	Cyclists, n=54	Controls, N=168	p<0.05
	B	R	C	N	
LVIDd, mm	50.24 (4.67)	49.77 (3.20)	50.68 (3.35)	47.59 (2.89)	B,R,C>N
IVSTd, mm	9.60 (1.61)	10.02 (1.22)	9.49 (1.16)	8.41 (1.11)	B,R,C>N
PWTd, mm	9.03 (1.55)	9.66 (1.10)	9.04 (1.35)	8.06 (1.06)	B,R,C>N, R>B
RWT, mm	0.37 (0.047)	0.40 (0.03)	0.37 (0.04)	0.35 (0.04)	B,R,C>N R>B,C
LVM, g	201.0 (66.9)	210.1 (51.1)	199.4 (50.17)	149.9 (35.9)	B,R,C>N
LVMI, g/m^2	108.7 (26.1)	117.3 (24.2)	117.9 (21.3)	85.6 (14.8)	B,R,C>N
IVSTd/ $BSA^{1/2}$	7.13 (0.98)	7.51 (0.78)	7.33 (0.67)	6.39 (0.70)	B,R,C>N
PWTd/ $BSA^{1/2}$	6.71 (0.94)	7.24 (0.73)	6.99(0.87)	6.13 (0.67)	B,R,C>N, R>B
LVIDd/ $BSA^{1/2}$	37.41 (2.27)	37.36 (2.31)	39.28(1.94)	36.22(1.80)	B,R,C>N C>B,R
LVM/ $BSA^{3/2}$	80.8 (18.3)	88.04 (18.4)	91.16 (15.05)	65.19 (10.75)	B,R,C>N, B<C,R
SF, %	38.54 (4.06)	38.63 (1.78)	38.44 (2.56)	37.6 (2.39)	B,R,C>N
E/A	1.88 (0.38)	2.08 (0.39)	2.05 (0.28)	1.89 (0.28)	B,R,C>N R,C>B

The highest PWTd was recorded in rowers comparing with basketball players and control group, and comparing also with cyclists, PWTd/BSA$^{1/2}$ and RWT were the highest in rowers. Cyclists had the highest LVM/BSA$^{3/2}$ as compared with analogous parameters in basketball players and control subjects and the highest LVIDd/BSA$^{1/2}$ as compared basketball players, rowers and control subjects. There was no difference in left ventricular FS among basketball players, rowers and cyclists, but rowers and cyclists had a greater E/A ratio than did basketball players and control subjects (Table 2.2.2.1).

An age-related comparison of echocardiographic parameters between control subjects and athletes involved in various sporting disciplines showed that in all age subgroups, the majority of echocardiographic parameters in athletes differed from analogous parameters in the control subjects. There were differences in echocardiographic parameters even between 12–13 year old athletes and control subjects: basketball players had greater IVSTd and IVSTd/BSA$^{1/2}$ than did control subjects, whereas in rowers and cyclists, all absolute echocardiographic parameters and parameters indexed to body surface area, except IVSTd/BSA$^{1/2}$ in rowers and RWT in cyclists, were greater than analogous parameters in the control group subjects. Basketball players, cyclists and rowers aged 14–15 years had greater all absolute echocardiographic parameters and parameters indexed to BSA, except for LVIDd/BSA$^{1/2}$ in rowers, than did subjects in the control group. Similarly, in 16–17-year-old basketball players, rowers and cyclists, all absolute echocardiographic parameters and parameters indexed to body surface area, except left ventricular RWT in cyclists, were found to be greater than analogous parameters in the control group (Table 2.2.2.2).

Table 2.2.2.2. *Age-relate comparison of echocardiographic parameters between athletes and controls. Data are expressed as mean ± SD*

Parameter	12–13 years		14–15 years		16–17 years	
	Athletes, n=39	**Controls, n=36**	**Athletes, n=60**	**Controls, n=68**	**Athletes, n=68**	**Controls, n=64**
LVIDd, mm	46.14±2.29	44.80±2.89	50.12±3.50	47.71±2.60	52.7±2.65	49.0±1.94
IVSTd, mm	8.19±0.81	7.31±0.99	9.67±1.05	8.46±0.87	10.6±1.10	9.0±0.93
PWTd, mm	7.88±1.04	7.21±0.91	9.25±1.23	8.05±0.89	10.0±1.07	8.6±0.99
RWT	0.35± 0.04	0.33±0.04	0.38±0.04	0.35±0.03	0.4±0.04	0.4±0.04
LVM, g	119.36± 19.2	99.79±20.43	171.12±36.71	131.13±22.94	206.1±29.95	148.4±23.13
LVMI, g/m^2	79.93±11.93	66.13±9.99	95.74±16.49	74.99±11.82	109.6±16.77	80.2±9.96
LVIDd/BSA, cm/m^2	**3.11±0.35**	3.00±0.21	**2.83±0.30**	2.74±0.27	2.8±0.23	2.7±0.15
E/A	**1.87±0.28**	1.87±0.21	**2.00±0.40**	1.89±0.32	2.1±0.36	1.9±0.28
IVSTd/$BSA^{1/2}$, mm/m	6.71±0.63	5.97±0.77	7.26±0.75	6.41±0.66	7.7±0.80	6.6±0.61
LVPWTd/$BSA^{1/2}$, mm/m	6.45±0.78	5.88±0.66	6.94±0.88	6.09±0.62	7.3±0.79	6.3±0.69
LVIDd/$BSA^{1/2}$, mm/m	37.83±2.51	36.59±1.83	37.61±2.23	36.14±2.14	38.4±2.31	36.1±1.31
LVM/$BSA^{3/2}$, g/m^3	74.55±13.49	60.01±9.71	84.21±16.56	64.99±11.86	95.1±16.73	68.3±8.92
LVIDd/$height^{2,7}$	**12.22±1.58**	12.28±1.71	**10.80±1.42**	10.47±1.19	10.6±1.14	10.1±0.89
LVM/$height^{2,7}$	31.53±5.71	27.05±4.89	36.47±6.9	28.62±4.8	41.5±6.98	30.6±4.61

All p values are less than 0.05, except given in bold.

Absolute LV echocardiographic parameters of athletes in all age groups were significantly greater than analogous parameters in the control group. This difference remained even after indexation of echocardiographic parameters to BSA and height, except for indexed LV internal diameter at end diastole (LVIDd/BSA and LVIDd/height$^{2.7}$), which did not differ comparing 12–13- and 14–15-year-old athletes with the control group. In addition, there was no difference in the parameter of LV diastolic function – E/A – between 12–13- and 14–15-year-old athletes and control group. Meanwhile, all absolute LV echocardiographic parameters and parameters indexed to BSA and height, E/A and FS of 16–17-year-old athletes exceeded analogous parameters of the control group. There were greater differences in IVSTd and LVPWTd than in LVIDd comparing athletes with controls. LVPWTd and LVM in rowers aged 12–13 years, LVPWTd, IVSTd and IVSTd/BSA$^{1/2}$ in 14–15-year olds, and IVSTd and LVPWTd in 16–17-year-olds exceeded the same parameters in basketball players. The greatest RWT, as compared with analogous parameter in basketball players and cyclists, was recorded in rowers aged 14–15 years. LVIDd/BSA, LVIDd/BSA$^{1/2}$ and LVMI in 12–13- and 16–17-year-old cyclists and LVMI in 14–15-year-old cyclists were greatest as compared to analogous parameters in basketball players and rowers.

2.3. Limits of echocardiographic parameters, which can be used for differentiation between physiological left ventricular hypertrophy and pathological left ventricular hypertrophy in athletes

Aiming at identifying the cutoff values of LV echocardiographic parameters, which would help in differentiating physiological left ventricular hypertrophy from cardiomyopathy in athletes, IVSTd and LVIDd of athletes were compared to predicted upper limits of these parameters, derived from the control group by calculating mean values for every year of age [Makan et al, 2005].

2.3.1. Predicted upper limits for left ventricular internal diameter at end diastole in athletes

LVIDd exceeded predicted upper limits in 47.9% of athletes. The highest predicted upper limit of LVIDd was 53.57 mm (54 mm). None of the 168 control subjects had LVIDd exceeding 54 mm; meanwhile, in athletes, LVIDd exceeding 54 mm and 60 mm was recorded in 9.6% and 1.2% of cases, respectively. One of athletes (0.5%) with LVIDd exceeding 60 mm had dilated cardiomyopathy.

Athletes with the LVIDd greater than predicted were represented by each of the sporting discipline in the study group, but most commonly cycling and basketball (55.6% and 51.6% respectively). LVIDd exceeding the predicted upper limits was more frequent in athletes aged 16–17-year (70%) than 12–13- year (30%) (Fig. 2.3.1.1).

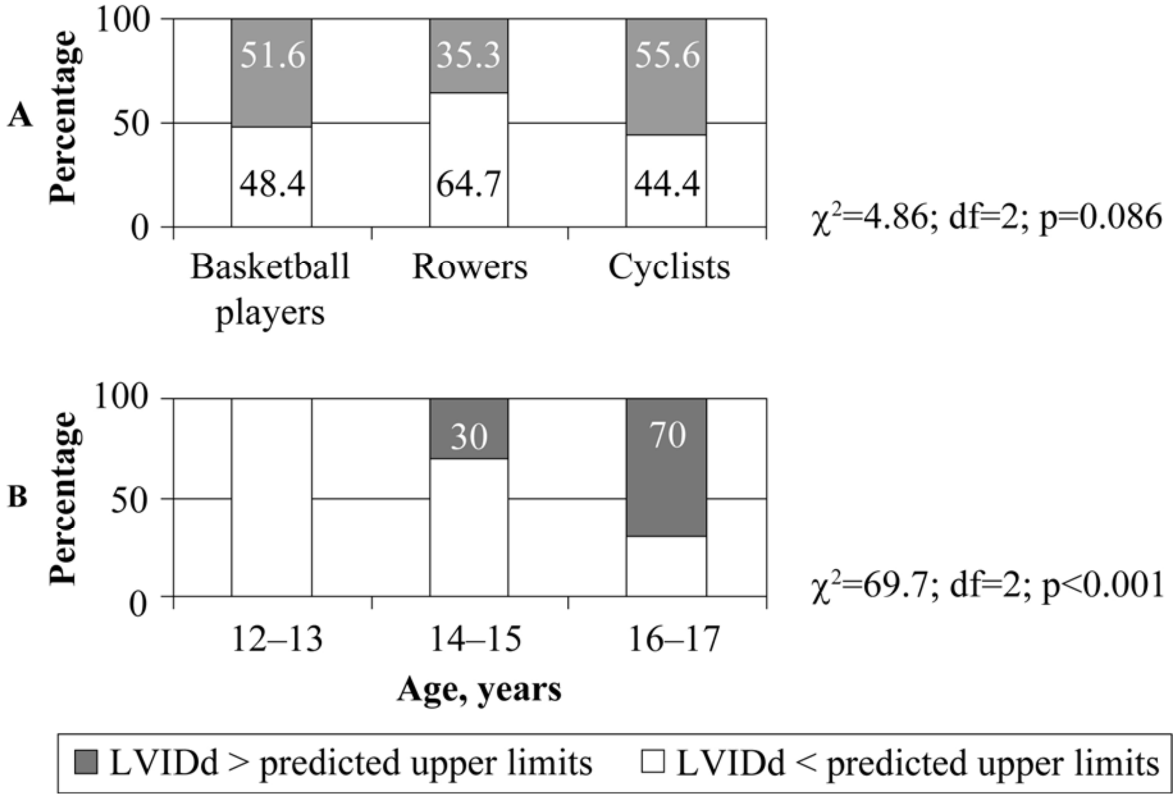

Fig. 2.3.1.1. *Distribution of athletes who had LVIDd exceeding the predicted upper limits by sporting discipline (A) and age (B)*

The predicted upper limits = 2 standart deviations from the mean calculated from the control subjects

Athletes with LVIDd exceeding predicted limits were older and had a greater body surface area. In addition, they were engaged in sports for longer and performed training of more intensive load than those with LVIDd falling within predicted limits. Athletes with LVIDd exceeding predicted limits had several echocardiographic features permitting differrentiation from dilated cardiomyopathy. They had increased other LV echocardiographic parameters such as IVSTd, IVSTd/BSA$^{1/2}$, LVPWTd, LVM. However, there was no significant difference in left ventricular RWT comparing both groups, which is considered as an index of left ventricular concentricity. In addition, no differences were found in left ventricular FS and E/A, that suggest that the increased LV wall thickness (IVSTd, LVPWTd) indicated physiological LV hypertrophy rather than the compensory hypertrophy in dilated cardiomyopathy (Fig. 2.3.1.2).

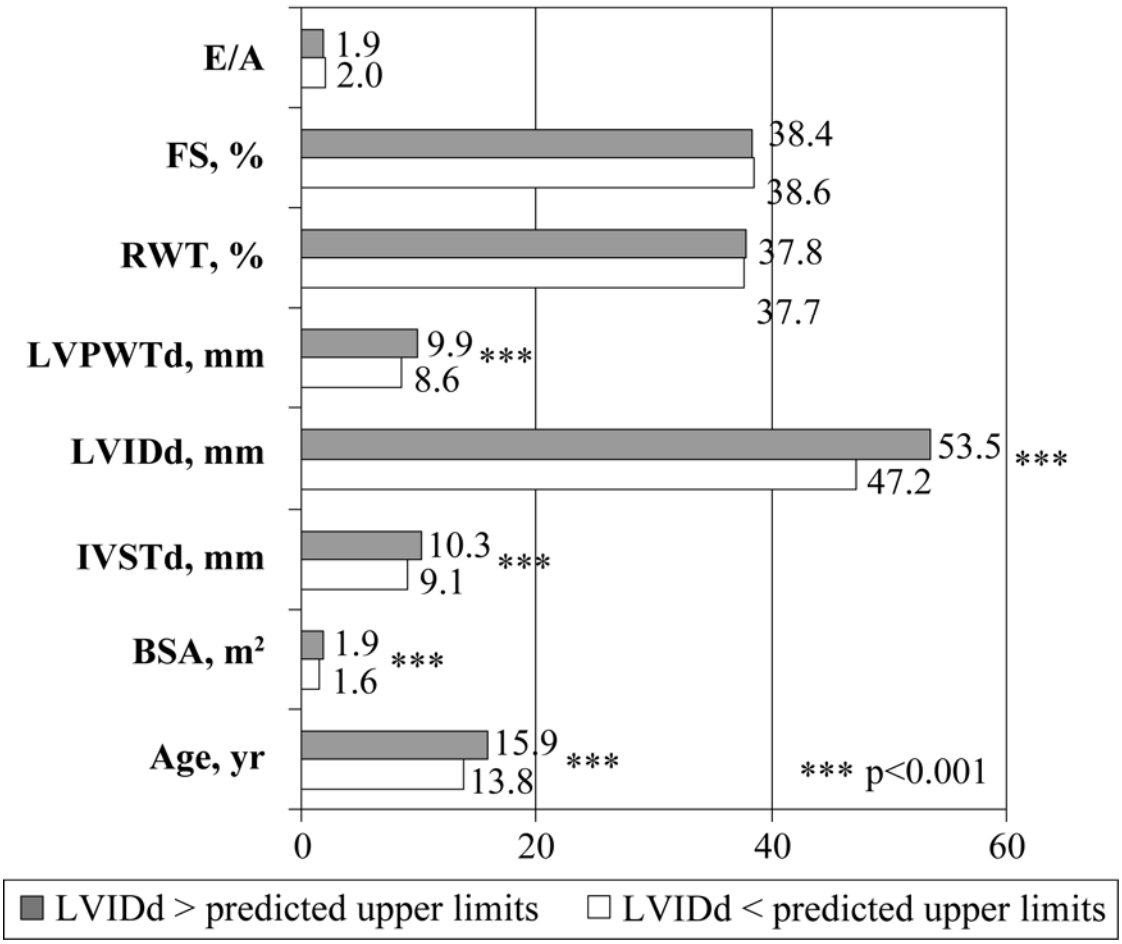

Fig. 2.3.1.2. *Comparison of demographic, antropometric and echocardiographic variables between athletes with LV cavity exceeding predicted limits and athletes with LV cavity size within predicted limits*

The predicted upper limits = 2 standart deviations from the mean calculated from the control subjects

Independent factors determining the value of LVIDd exceeding the predicted upper limits were older age (16–17 years old), higher body weight (OR=1.08; $p<0.001$) and sporting discipline, i.e. athletes engaged in rowing were less likely to have an LVIDd exceeding the predicted upper limits than athletes engaged in cycling (OR=0.18, $p<0.01$).

2.3.2. Predicted upper limits for interventricular septal thickness in athletes

Establishing the predicted limits of IVSTd revealed that the highest predicted upper limit of IVSTd was 10.86 mm (11 mm). It was determined that 76% of athletes had an IVSTd value exceeding the predicted upper limits; they were represented by each of the sporting discipline. IVSTd value exceeding the predicted upper limits was more frequent in athletes aged 16–17-years (98.5%) and 14–15-years (81.7%) (Fig. 2.3.2.1).

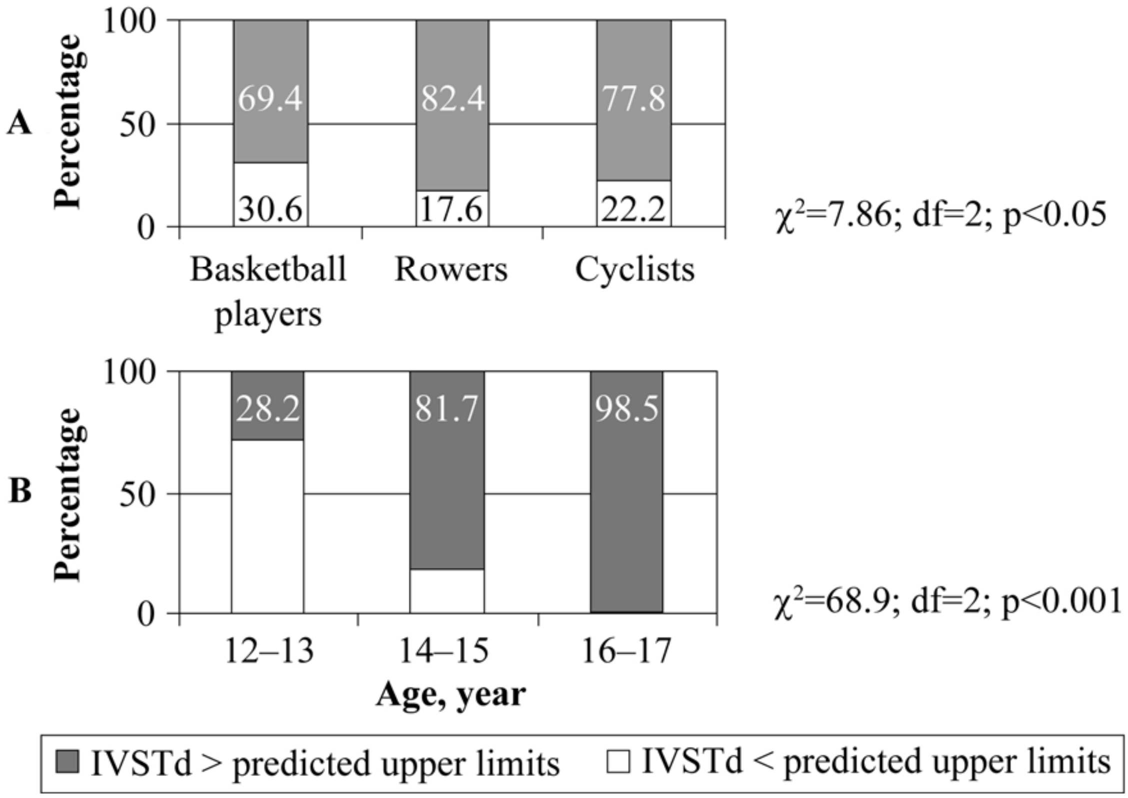

Fig. 2.3.2.1. *Distribution of athletes who had IVSTd exceeding the predicted upper limits by sporting discipline (A) and age (B)*

The predicted upper limits = 2 standart deviations from the mean calculated from the control subjects

Athletes with IVSTd exceeding predicted limits were older and had a greater body surface area than those with IVSTd falling within predicted limits. They were engaged in sports for longer and performed training of more intensive load.

In addition, they had LVIDd exceeding predicted limits that suggest that the increased IVSTd indicated physiological LV hypertrophy. In contrast, patients with hypertrophic cardiomyopathy have a small or normal-sized LVIDd. Athletes with IVSTd exceeding predicted limits also had increased LVPWTd, LVM and RWT. There was no significant difference in left ventricular FS comparing both groups, but E/A ratio was greater than those with IVSTd falling within predicted limits (Fig. 2.3.2.2).

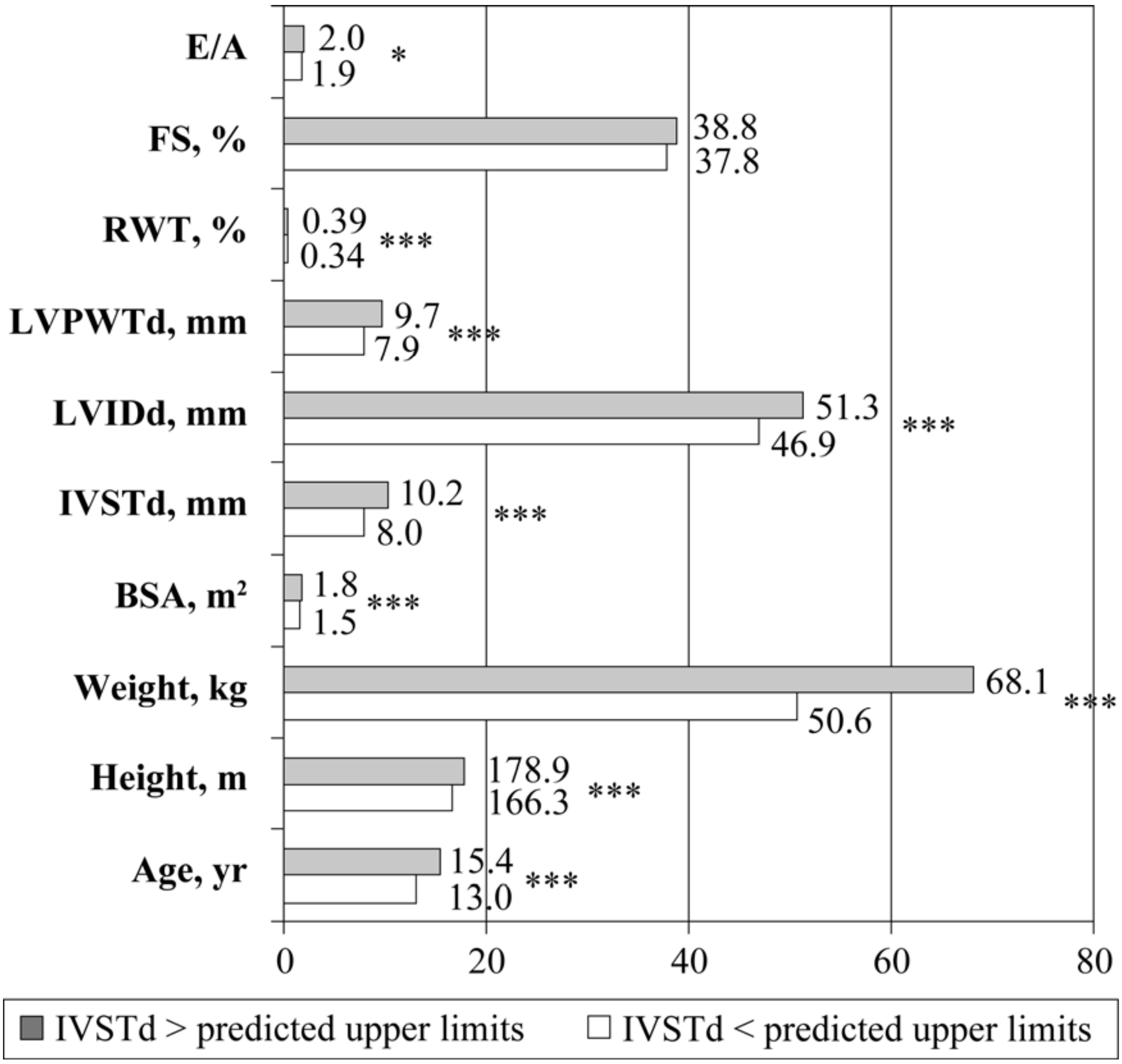

Fig. 2.3.2.2. *Comparison of demographic, antropometric and echocardiographic variables between athletes with IVSTd exceeding predicted limits and athletes with IVSTd within predicted limits*

The predicted upper limits = 2 standart deviations from the mean calculated from the control subjects

Independent factors determining IVSTd values exceeding predicted limits were as follows: athlete's age (16–17 years), higher body weight (OR=1.12, 95% CI 1.04–1.21; p=0.004), longer training duration (OR=4.86, 1.39–17.05, p=0.013), greater training volume (OR=1.13, 1.08–1.81, p=0.032) and sporting discipline i.e. basketball players were less likely to have IVSTd exceeding predicted limits than did cyclists (OR=0.07, 0.01–0.60, p=0.015). Training duration was the strongest independent factor associated with IVSTd exceeding the predicted limits.

2.4. Left ventricular geometry in athletes

Abnormal LV geometry was present in 46.9% of all athletes: 34.1% of athletes had eccentric hypertrophy, 16.2% concentric LV hypertrophy and 6.6% concentric remodeling (Fig. 2.4.1).

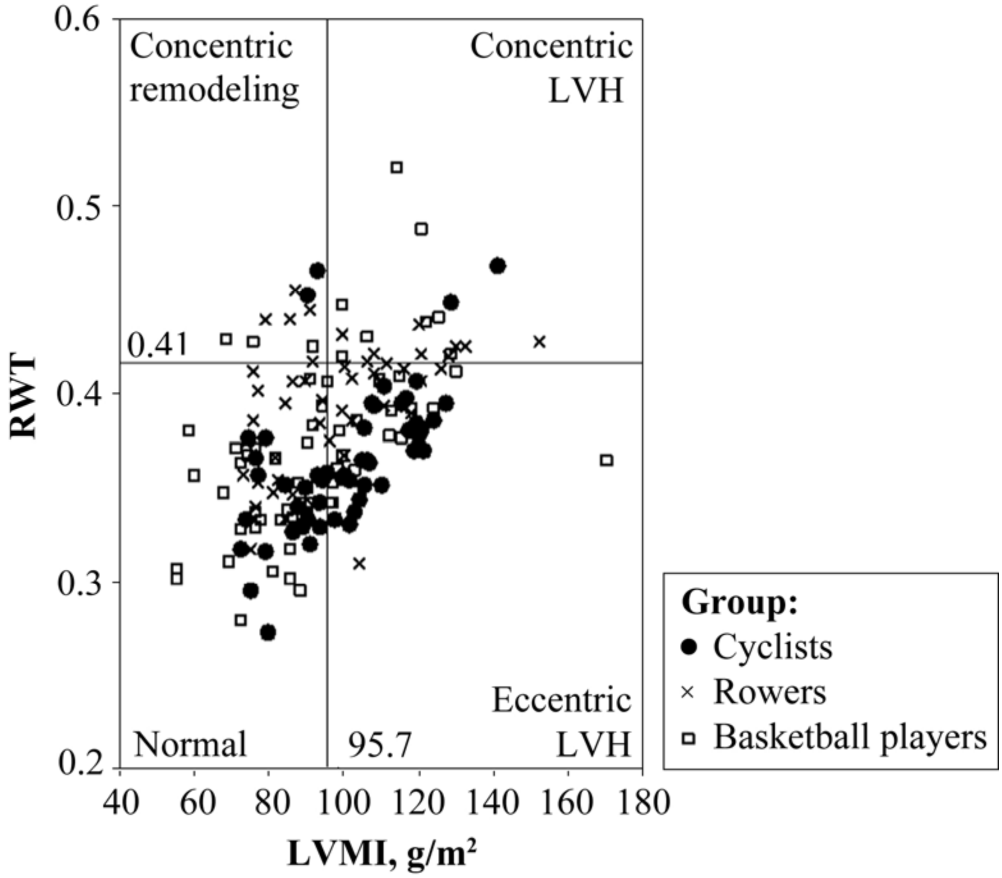

Fig. 2.4.1. *Relation between left ventricular mass (LVM) normalized to body surface area and relative wall thickness (RWT) in athletes of different sporting discipline*

Reference lines represent the 95th percentile in control subjects

Normal LV geometry was most prevalent among basketball players (53.2%) and eccentric LV hypertrophy among cyclists (53.7%). The proportions of rowers and basketball players having concentric and eccentric LV hypertrophy were similar, but rowers had concentric LV hypertrophy more frequently than eccentric LV hypertrophy (29.4% versus 21.1%). Meanwhile, in basketball players, eccentric LV hypertrophy was more prevalent as compared with concentric LV hypertrophy (25.8% versus 16.1%). Left ventricular remodeling was more common among rowers (11.8%) than among cyclists (3.7%) and basketball players (4.8%). Altered LV geometry was most prevalent among 16–17-year-old athletes (82.4%) and least prevalent among 12–13-year-old athletes (12.8%) (Fig. 2.4.2).

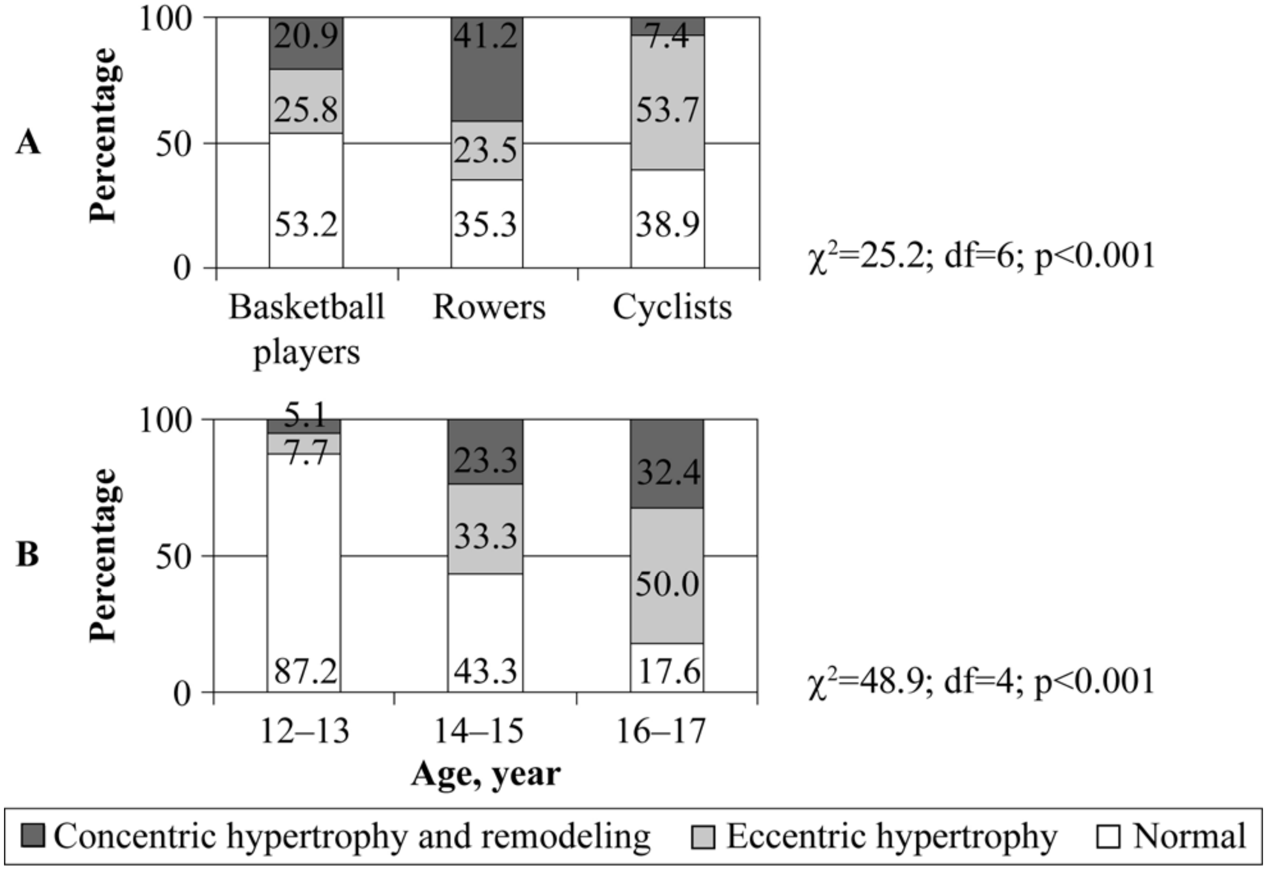

Fig. 2.4.2. *Distribution of left ventricle geometry in athletes by sporting discipline (A) and age (B)*

Correlation analysis showed that LV geometry exhibited a moderate correlation with age (*r*=0.49), body weight (*r*=0.36), BSA (*r*=0.36) and training volume (*r*=0.53).

After multivariable adjustment (Table 2.4.1), an independent association was found between eccentric LV hypertrophy and age (compared to age of 12–13 years in the age of 14–15 years OR=16.3, in the age of 16–17 year OR=48.6), more intensive training (each hour per week of training by 2.6 times increased the risk for eccentric LV hypertrophy), and cycling sport discipline (OR=10.5, p<0.001).

Table 2.4.1. *Independent predictors of LV geometry in athletes*

Predictor	Left ventricle geometric pattern			
	Eccentric LV hypertrophy		Concentric LV hypertrophy[a]	
	OR (95% CI)	**p**	**OR (95% CI)**	**p**
Age, years		$p_{for\ trend}$=0.001		$p_{for\ trend}$=.050
12–13 #	1		–	–
14–15	16.3 (2.9–92.2)	0.002	0.3 (0.1–0.8)	0.016
16–17	48.6 (3.8–62.4)	0.003	1	
Training, h/wk	2.6 (1.04–6.7)	0.042		
Age*training, yr	0.7 (0.5–1.0)	0.061		
Sport		$p_{for\ trend}$=0.002		$p_{for\ trend}$=0.003
Basketball players#	1		1	
Rowers	1.6 (0.6–4.5)	0.401	2.5 (0.9–6.7)	0.048
Cyclists	10.5 (3.6–30.7)	<0.001	0.1 (0.01–0.7)	0.023
R^2=38.7 %			R^2=36%	

[a] including LV concentric remodeling; CI, confidence interval; OR, odds ratio; R^2, corrected coefficient of determination.

The probability of LV concentric geometry was significantly more in rowers (OR=2.5, p<0.05) in age 16–17 years.

2.5. Functional parameters of the cardiovascular system, speed of their changes during physical load and associations with echocardiographic parameters in athletes and controls

HR at rest was lower in athletes than in subjects from the control group, meanwhile there was no difference in SBP between athletes and controls. During the maximal physical load, higher SBP was documented in athletes as compared to the control group, SBP in rowers was higher than an analogous parameter in cyclists and basketball players (Fig. 2.5.1).

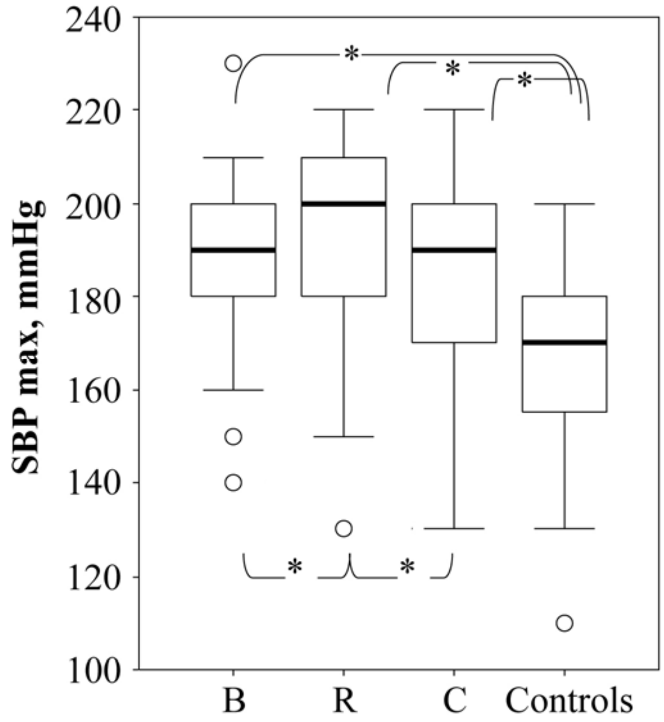

Fig. 2.5.1. *Systolic blood pressure (SBP) during maximal load within each sporting discipline for 166 athletes and 168 controls*

B, basketball players; R, rowers; C, cyclists; Central lines indicates median, lower and upper box borders the 25th and 75th, and extension borders the 10th and 90th distribution percentiles; *$p<0.05$.

With the aim to evaluate more precisely the adaptation of the body to long-term physical load, speeds of changes in functional parameters (HR, JT interval, JT/RR, SBP, SBP–DBP) were derived during physical load, i.e. it was determined how much functional indices were increased for one watt of load every second minute of physical load (Fig. 2.5.2).

There were significant differences in speed of changes in HR, JT/RR, SBP and SBP–DBP between athletes and controls at the second, sixth and eight minutes: in athletes, speed of changes in HR was lower, speed of changes in SBP, SBP–DBP and JT/RR was lower at the second and eight minutes of physical load, and at the sixth minute, these parameters were greater than analogous ones in the control group. A significant difference in speed of changes in JT between athletes and control subjects was shown only at the sixth minute of physical load. Lower speed of changes in HR, JT, JT/RR, SBP, SBP–DBP may show a better adaptation to load.

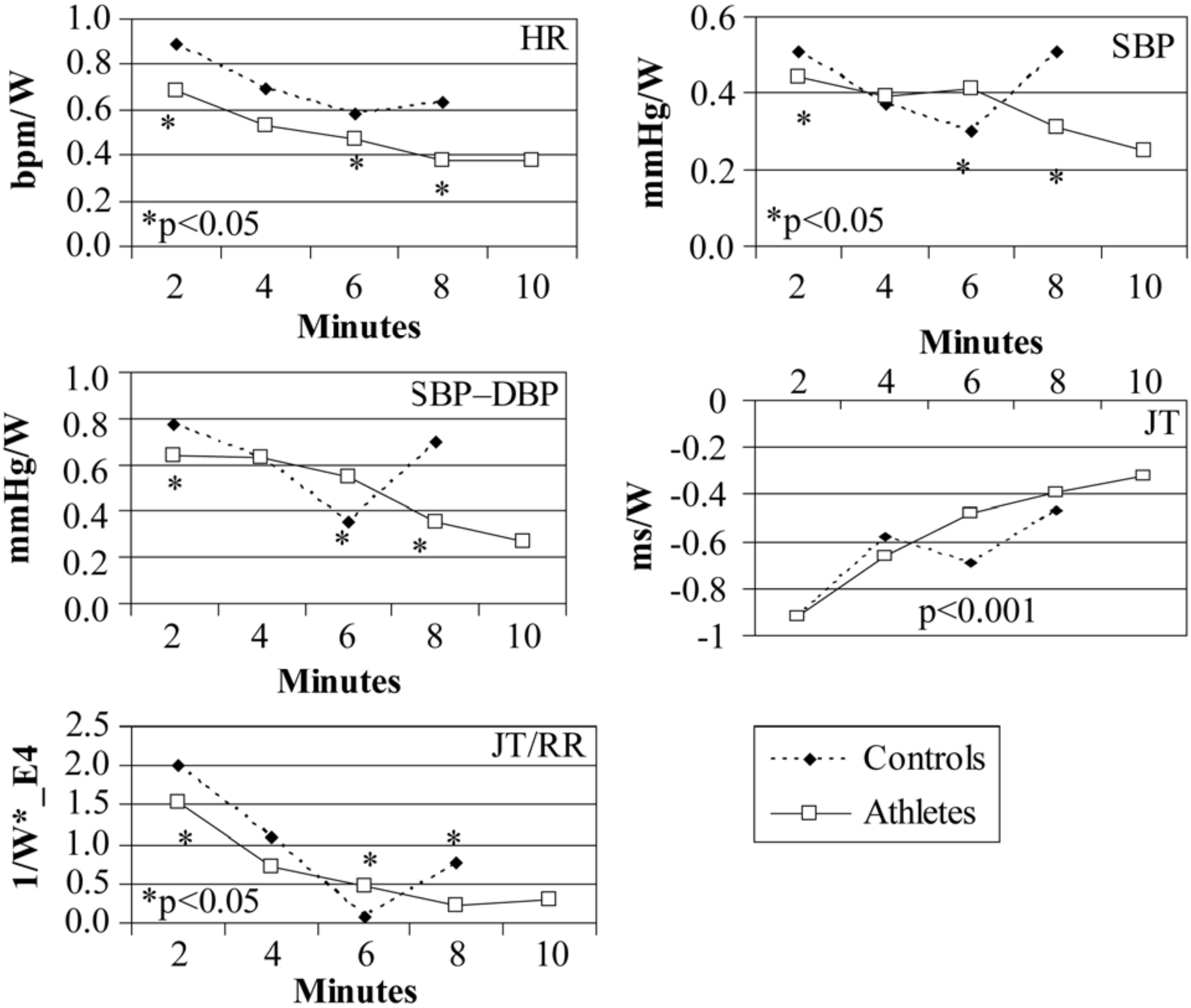

Figure 2.5.2. *Speed of changes in functional indices for athletes (N=166) and control subjects (N=168) during the physical load*

HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; JT, JT interval; RR, interval RR.

During the physical load, speed of changes in all functional indices of athletes was decreasing equally, except for speed of changes in SBP and SBP–DBP, which from the fourth minute to the sixth minute remained almost the same and from the sixth minute started to decrease.

Speed of changes in JT/RR in athletes, before reaching the maximum of physical load, decreased and in the last step of physical load has increased. In the control subjects the speed of changes in nearly all functional indices (HR, JT/RR, SBP, SBP–DBP), before reaching the maximum of physical load, suddenly decreased and in the last step of physical load has increased except for the speed of changes in JT, which decreased earlier at the fourth minute, from the fourth to sixth minute increased and from the sixth to eight minute again decreased.

In athletes, relationship between speed of changes in HR and either LVM or LVMI during the whole physical load was identified (Fig. 2.5.3). Even at the beginning of physical load, speed of changes exhibited a poor inverse correlation with LVM (r=–0.22) and a moderate inverse correlation with LVMI in athletes (r=–0.35). At the sixth minute of physical load, there was a significant but weak inverse correlation between speed of changes in HR and either LVM or LVMI (r=–0.15, $p<0.05$ and r=–0.22, $p<0.05$, respectively). There was no significant relationship between speed of changes in SBP and either LVM or LVMI in athletes. In controls, the speed of changes in HR and SBP were not associated with LVM or LVMI.

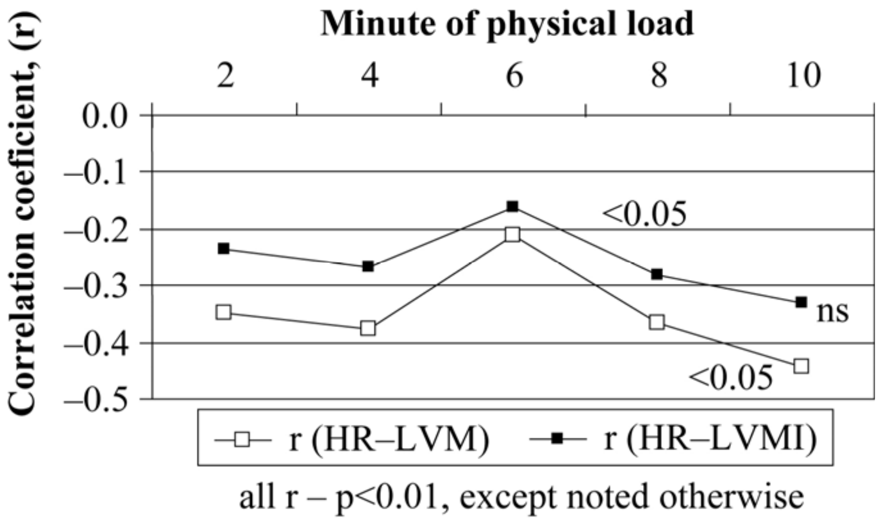

Fig. 2.5.3. *Association of left ventricular mass (LVM) and mass index (LVMI) with speed of changes in heart rate (HR) with increasing exercise load in bicycle ergometry in athletes*

HR, heart rate (bpm); LVM, left ventricular mass (g);
LVMI, left ventricular mass index (g/m^2)

CONCLUSIONS

1. All absolute left ventricular echocardiographic parameters were greater in athletes than in non-athletes. This difference remained even after indexation of parameters to body surface area and height, except for left ventricular internal diameter at end diastole indexed to height.
2. Independent factors influencing left ventricular echocardiographic parameters in athletes were age, body weight, body surface area, training duration, training volume and sporting discipline. Systolic

blood pressure at rest and maximal physical load had no significant impact on echocardiographic parameters.

3. Abnormal left ventricular geometry was present in 46.9% of all athletes. Eccentric hypertrophy was most common, concentric remodeling was least common. Age, training duration, training volume and cycling as a sporting discipline were significantly associated with eccentric hypertrophy; age and rowing as a sporting discipline had a significant impact on concentric hypertrophy.

4. Interventricular septal thickness in 76% of cases, left ventricular internal diameter at end diastole in 47.9% of cases and left ventricular internal end-diastolic diameter index in 8.4% of cases exceeded the predicted limits, but only 1.7% of athletes had interventricular septal thickness greater than 12 mm and 1.2% of athletes – left ventricular internal diameter at end diastole greater than 60 mm.

5. Athletes demonstrated lower heart rate at rest, systolic blood pressure during the maximal physical load and lower speed of changes in functional parameters of the cardiovascular system during the maximal physical load (HR, SBP, JT interval, JT/RR, SBP–DBP) as compared to the control subjects. Before reaching the maximal physical load, speed of changes JT/RR in athletes and all functional parameters (HR, SBP, JT, JT/RR, (SBP–DBP) in the control group was the lowest; during the last step of physical load it increased.

6. Left ventricular mass was associated with heart rate and systolic blood pressure in athletes: at rest it exhibited an inverse correlation with heart rate and a direct correlation with systolic blood pressure, and this association being maximal after reaching the maximal physical load. During the maximal physical load, a moderate correlation was observed between left ventricular mass and speed of changes in heart rate in athletes.

This study confirmed the hypothesis that echocardiographic parameters and speed of changes in functional parameters in athletic children and adolescents differ from that ones in subjects not engaged in sports activities and that a correlative relationship exits between left ventricular echocardiographic and functional parameters and speed of their changes. Echocardiographic parameters of children and adolescents engaged in sports are dependent on age, anthropometric data, training duration, training volume and sporting discipline.

PRACTICAL RECOMMENDATIONS

1. Analysis of speed of changes in functional parameters during cycle ergometer test can be applied in everyday practice of sports medicine for the evaluation of functional state of the human body and the cardiovascular system and aiming to optimise and individualise physical load in athletic children and adolescents.

2. Cutoff values of echocardiographic parameters identified in this study can help in evaluation of physiological left ventricular hypertrophy with the aim to differentiate it from hypertrophic and dilative cardiomyopathy and to avoid hyperdiagnosis of hypertrophic cardiomyopathy. All athletes with echocardiographic parameters exceeding predicted limits should be referred for a thorough examination due to cardiomyopathy.

PUBLICATIONS ON THE DISSERTATION THEME

1. Bartkevičienė A, Vainoras A, Bakšienė D, Brožaitienė J, Raškauskienė N, Kibildienė S, Rožnova N. Sportuojančių vaikų ir paauglių širdies ir kraujagyslių sistemos funkciniai ypatumai. *Ugdymas. Kūno kultūra. Sportas.* 2008;2(69):5-7.
2. Bartkevičienė A, Vainoras A, Bakšienė D, Raškauskienė N, Kibildienė S, Rožnova N, Brožaitienė J. Assessment of functional parameters of cardiovascular system in children and adolescent athletes. 2nd International Scientific Conference *Physical Culture and Sport in Universities*, 31 May, 2008.
3. Bartkevičienė A, Vainoras A, Bakšienė D, Raškauskienė N, Kibildienė S. Assessment of structural cardiac adaptation and parameters of cardiovascular system in children and adolescent basketball players. 2nd International Scientific Conference *Current Issues and New Ideas in Sport Science*, 16-17 October, 2008.
4. Bartkevičienė A, Vainoras A, Bakšienė D, Brožaitienė J, Raškauskienė N, Kibildienė S, Rožnova N. Ilgalaikio fizinio krūvio poveikis 12-17 metų krepšininkų širdies kairiojo skilvelio morfometrijai ir funkcijai. *Biologinė psichiatrija ir psichofarmakologija.* Thesis of VIII

Annual meeting of Institute of Psychophysiology and Rehabilitation c/o Kaunas University of Medicine 2008; t.10, Nr.2, psl.:32.

5. Bartkevičienė A, Vainoras A, Bakšienė D, Brožaitienė J, Raškauskienė N, Kibildienė S, Rožnova N. Ilgalaikio fizinio krūvio poveikis 12–17 metų krepšininkų širdies kairiojo skilvelio morfometrijai ir funkcijai. *Biologinė psichiatrija ir psichofarmakologija.* Thesis of VIII Annual meeting of Institute of Psychophysiology and Rehabilitation c/o Kaunas University of Medicine 2008; t.10, Nr.2, psl.:32.
6. Bartkevičienė A, Vainoras A, Bakšienė D, Raškauskienė N. Left ventricular geometry in young athletes (Poster presentation, thesis). *Cardiology.* 2009; 113(1):107. 22th Nordic-Baltic Congress of Cardiology, June 3-5, 2009, Reikjavik, Iceland. Abstract No. 100.
7. Bartkevičienė A, Vainoras A, Bakšienė D, Brožaitienė J, Raškauskienė N, Kibildienė S. 12–17 metų krepšininkų širdies echokardiografinių ir funkcinių rodmenų ypatumai. *Ugdymas. Kūno kultūra. Sportas.* 2009; 2 (73):4-13.

Other publications:

1. Vasiliauskas D, Venckūnas T, Marcinkeviciene J, Bartkeviciene A. Development of structural cardiac adaptation in basketball players. *European Journal of Cardiovascular Prevention and Rehabilitation* 2006;13, 985-989.
2. Bartkevičienė A, Bakšienė D. Sportuojančių vaikų ir paauglių širdies morfometrinių parametrų pokyčiai ir kairiojo skilvelio funkcija. *Medicina (Kaunas*) 2007; 43(3), 251-58.

SANTRAUKA

Organizmui prisitaikant prie nuolatinio fizinio krūvio, vyksta sudėtingi, kompleksiniai, tarpusavyje susiję daugelio organų sistemų struktūriniai bei funkciniai pokyčiai. Didžiausias vaidmuo visoje adaptacijos prie fizinio krūvio mechanizmų grandinėje tenka širdies ir kraujagyslių sistemai, kurios funkcinis pajėgumas ne tik lemia organizmo adaptaciją prie ilgalaikio fizinio krūvio, bet dažnai tampa veiksniu, ribojančiu organizmo adaptacinius procesus. Intensyvaus ir nuolatinio fizinio krūvio metu gali būti viršijamos fiziologinių pokyčių ribos, o tai gali sukelti sveikatai ir gyvybei grėsmingas situacijas. Fizinio krūvio poveikis suaugusių sportininkų širdies ir kraujagyslių sistemai yra plačiai nagrinėjamas. Tačiau apie fizinio krūvio įtaką vaikų ir paauglių organizmui žinoma nepakankamai. Todėl svarbu tiksliai įvertinti sportuojančių vaikų ir paauglių širdies ir kraujagyslių sistemos bei viso organizmo adaptacinius pokyčius, atskirti juos nuo patologinių būklių, laiku nustatyti ikiklinikinius deadaptacijos reiškinius bei juos koreguoti, individualizuojant ir optimizuojant fizinį krūvį.

Darbo tikslas

Įvertinti fizinio krūvio poveikį sportuojančių vaikų ir paauglių kairiojo skilvelio morfometrinių bei širdies ir kraujagyslių sistemos funkcinių rodiklių pokyčiams, išanalizuoti jų tarpusavio ryšį bei nustatyti veiksnius, turinčius įtaką sportuojančių vaikų ir paauglių kairiojo skilvelio morfometriniams rodikliams.

Darbo uždaviniai:

1. Įvertinti sportuojančių vaikų ir paauglių kairiojo skilvelio echokardiografinius rodiklius ir palyginti su kontrolinės grupės tiriamųjų atitinkamais rodikliais.

2. Nustatyti amžiaus, ūgio, kūno svorio, kūno paviršiaus ploto sporto šakos, treniravimosi trukmės, treniravimosi krūvio, sistolinio kraujospūdžio ramybės ir maksimalaus fizinio krūvio metu įtaką sportuojančių vaikų ir paauglių kairiojo skilvelio echokardiografiniams rodikliams.

3. Įvertinti sportuojančių vaikų ir paauglių kairiojo skilvelio geometriją ir nustatyti veiksnius, turinčius įtaką KS geometrijai.

4. Įvertinti sportuojančių vaikų ir paauglių tarpskilvelinės pertvaros storio ir kairiojo skilvelio galinio diastolinio dydžio ribinių reikšmių prognozavimo galimybę.

5. Įvertinti sportuojančių vaikų ir paauglių širdies ir kraujagyslių sistemos funkcinius rodiklius bei jų kitimo greitį ir palyginti su kontrolinės grupės tiriamųjų atitinkamais rodikliais.

6. Nustatyti sąsajas tarp sportuojančių vaikų ir paauglių širdies ir kraujagyslių sistemos funkcinių ir kairiojo skilvelio echokardiografinių rodiklių.

Tiriamųjų kontingentas ir tyrimo metodai

Tiriamųjų grupę sudarė vyriškos lyties 12–17 metų 167 sportininkai (amžiaus vidurkis 14,8±1,6 metų) ir tos pačios lyties 12–17 metų 168 nesportuojantieji (amžiaus vidurkis ±1,6 metų), kurie sudarė kontrolinę grupę. Tiriamieji pagal sporto šakas buvo suskirstyti į tris grupes: krepšininkų (37,2 proc.), irkluotojų (30,5 proc.) ir dviratininkų (32,3 proc.). Pagal amžių tiriamieji buvo suskirstyti į tris pogrupius: 12–13 metų, 14–15 metų ir 16–17 metų.

Tiriamieji buvo pasverti, pamatuotas jų ūgis. Visiems tiriamiesiems ultragarso aparatu „Philips" su 3,5 MHz davikliu buvo atliktas echokardiografinis tyrimas, kurio metu priekrūtinkauliniame ilgosios ašies vaizde ties dviburio vožtuvo burių galais vienmačiu metodu (M rėžimu) diastolės pabaigoje išmatuoti šie echokardiografiniai rodikliai: tarpskilvelinės pertvaros storis diastolėje ir sistolėje, kairiojo skilvelio galinis diastolinis dydis, kairiojo skilvelio galinis sistolinis dydis bei kairiojo skilvelio užpakalinės sienelės storis. Pagal formules apskaičiuotas kairiojo skilvelio frakcinis sutrumpėjimas (FS), kairiojo skilvelio miokardo masė (KS MM), miokardo masės indeksas (MMI) bei santykinis kairiojo skilvelio sienelių storis (SSS). Doplerinio echokardiografinio tyrimo metu kraujotakos per dviburį vožtuvą kreivėje buvo išmatuotas maksimalus ankstyvojo prisipildymo greitis E (m/s) ir maksimalus tėkmės per dviburį vožtuvą greitis susitraukiant prieširdžiams A (m/s) bei apskaičiuotas E/A santykis.

Siekiant palyginti skirtingo amžiaus ir antropometrinių duomenų tiriamųjų kairiojo skilvelio echokardiografinius rodiklius, apskaičiuoti su kūno paviršiaus plotu bei ūgiu susiję echokardiografiniai rodikliai.

Aparatu Ergocard II (Archimed 4220) 166 sportininkams ir 168 kontrolinės grupės buvo atliktas veloergometrinis mėginys. Pagal McMaster protokolą taikytas nepertraukiamas, kas dvi minutes pakopomis sunkėjantis fizinis krūvis iki submaksimalaus ŠSD arba krūvį ribojančių simptomų. Prieš tyrimą ramybės sąlygomis ir veloergometrinio mėginio metu kiekvienos krūvio pakopos paskutines 10 sek. buvo išmatuotas sistolinis (SAKS) ir diastolinis (DAKS) kraujospūdis, apskaičiuotas pulsinis spaudimas (SAKS–DAKS) bei užrašyta 12-kos derivacijų EKG. Ramybės bei kiekvienos krūvio pakopos metu buvo vertinami šie rodikliai: ŠSD, JT, JT/RR, SAKS, (SAKS-DAKS). Pagal formules apskaičiuoti šių rodiklių kitimo greičiai.

Statistinė analizė atlikta SPSS 15.0 programos paketu. Tikrinant statistines hipotezes, reikšmingumo lygmuo pasirinktas 0,05. Duomenų analizei taikyti aprašomosios ir lyginamosios statistikos bei statistinių ryšių vertinimo metodai. Aprašomajai rodiklių analizei taikyti standartiniai statistikos rodikliai: tolydiesiems kintamiesiems – parametrų aritmetinis vidurkis, jo standartinis nuokrypis, 95 proc. pasikliautinasis intervalas (PI), dispersija, mediana; nominaliems – pasiskirstymo proporcijos (95 proc. PI). Kiekybinių dydžių lyginimas atliktas taikant Studento (t) ir Fišerio kriterijus.

Tikrinant statistines hipotezes, atitinkamai normaliojo skirstinio atitikimo kriterijams, buvo taikomi parametriniai (porinis ir neporinis t-testas, ANOVA, tiesinė regresija ir Pearson‘o tiesinės koreliacijos koeficientas) ar neparametriniai testai mažų imčių statistiniam reikšmingumui nustatyti (Mann-Whitney), Kruskal-Wallis kriterijai (3 grupės ir daugiau), ryšiui tarp dviejų kintamųjų – Spearman‘o ranginis koreliacijos koeficientas. Kokybinių požymių tarpusavio priklausomumui vertinti naudotas χ^2 kriterijus. Grupių palyginimui taikyta vienfaktorinė (One-Way ANOVA) ir daugelio faktorių dispersinė analizė (daugkartinio lyginimo aposteriorinis (post hoc) Bonferroni‘o kriterijus). Siekiant nustatyti nepriklausomus tiriamųjų KS echokardiografinių rodiklių veiksnius, buvo sudaromi daugiamatės regresijos modeliai. Nepriklausomi kintamieji buvo amžius, ūgis, kūno svoris, kūno paviršiaus plotas, treniravimosi trukmė ir treniravimosi krūvis, SASK ramybės ir maksimalaus fizinio krūvio metu. Priklausomi kintamieji – tiriamųjų KS echokardiografiniai rodikliai (TSP, KSGDd. KSUS, KS MM).

Prognozuojamos echokardiografinių rodiklių (TSP, KSGDd) viršutinės ribinės reikšmės apskaičiuotos kiekvieniems sportininkų amžiaus metams pagal kontrolinės grupės tiriamųjų TSP ir KSGDd reikšmių vidurkius +2SN. Kairiojo skilvelio geometrijos analizei referentinės ribos buvo apskaičiuotos pagal kontrolinės grupės tiriamųjų santykinio sienelių storio ir miokardo masės indekso 95-tą procentilį.

Išvados:

1. Sportininkų visi absoliutūs echokardiografiniai rodikliai buvo reikšmingai didesni už kontrolinės grupės atitinkamus rodiklius. Šis skirtumas išliko ir indeksavus rodiklius pagal kūno paviršiaus plotą, išskyrus kairiojo skilvelio galinio diastolinio dydžio indeksą, kuris tarp krepšininkų bei irkluotojų ir kontrolinės grupės tiriamųjų nesiskyrė.
2. Nepriklausomi veiksniai, turėję įtakos sportininkų kairiojo skilvelio echokardiografiniams rodikliams buvo amžius, kūno svoris, kūno paviršiaus plotas, treniravimosi krūvis, treniravimosi trukmė bei sporto šaka. Sistolinis kraujospūdis ramybės ir maksimalaus fizinio krūvio metu reikšmingos įtakos neturėjo.
3. 46,9 proc. sportininkų nustatyta pakitusi kairiojo skilvelio geometrija. Dažniausiai sportininkams nustatyta kairiojo skilvelio ekscentrinė hipertrofija, rečiausiai – kairiojo skilvelio koncentrinis persimodeliavimas. Amžius, treniravimosi trukmė, treniravimosi krūvis bei dviračių sporto šaka turėjo reikšmingos įtakos ekscentrinei kairiojo skilvelio hipertrofijai, amžius bei irklavimo sporto šaka – koncentrinei kairiojo skilvelio hipertrofijai.
4. 76 proc. sportininkų tarpskilvelinės pertvaros storis, 47,9 proc. kairiojo skilvelio galinis diastolinis dydis viršijo ribines progonzuojamas reikšmes, tačiau tik 1,7 proc. sportininkų tarpskilvelinės pertvaros storis buvo didesnis už 12 mm, 1,2 proc. sportininkų kairiojo skilvelio galinis diastolinis dydis didesnis už 60 mm.
5. Sportininkų širdies susitraukimo dažnis ramybės metu bei širdies ir kraujagyslių sistemos funkcinių rodiklių (ŠSD, SAKS, JT intervalo, JT/RR, (SAKS–DAKS) kitimo greitis fizinio krūvio mėginio metu buvo mažesni už kontrolinės grupės tiriamųjų. Prieš pasiekiant fizinio krūvio maksimumą sportininkų – ŠSD bei JT/RR, o kontrolinės grupės visų funkcinių rodiklių (ŠSD, SASK, JT, JT/RR, (SASK–DASK) kitimo greitis buvo mažiausias, paskutinėje fizinio krūvio mėginio pakopoje – padidėjo.
6. Sportininkų kairiojo skilvelio miokardo masė buvo susijusi su širdies susitraukimo dažniu bei sistoliniu kraujospūdžiu: ramybėje neigiamai koreliavo su širdies susitraukimo dažniu, teigiamai – su sistoliniu kraujospūdžiu, maksimalaus fizinio krūvio metu miokardo masės koreliacinis ryšys su sistoliniu kraujospūdžiu sustiprėjo. Viso fizinio krūvio mėginio metu sportininkų kairiojo skilvelio

miokardo masė vidutinio stiprumo ryšiu buvo susijusi su širdies susitraukimo dažnio kitimo greičiu.

Darbo praktinė reikšmė

Pirmą kartą Lietuvoje atliktas sportuojančių vaikų ir paauglių širdies ir kraujagyslių sistemos bei organizmo funkcinės būklės kompleksinis tyrimas ne tik parodė ilgalaikio fizinio krūvio poveikį vaikų ir paauglių kairiojo skilvelio morfometriniams ir funkciniams rodikliams ir patvirtino šių rodiklių pokyčius įtakojančius veiksnius, bet ir atskleidė sąsajas tarp KS morfometrinių ir funkcinių rodiklių bei jų kitimo greičio. Remiantis širdies ir kraujagyslių sistemos funkcinių rodiklių kitimo greičio pokyčiais, galima laiku įvertinti sportininkų funkcinių galimybių ribą, individualizuoti bei optimizuoti fizinį krūvį. Sukauptus duomenis galima panaudoti studentų mokymui, sporto medicinos gydytojų bei kitų sveikatos priežiūros specialistų kvalifikacijos kėlimui. Remiantis tyrimo duomenimis, galima vykdyti sportuojančių vaikų sveikatos priežiūros programas.

CURRICULUM VITAE

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Education:

1965–1976 Kaunas 1st Secondary School (now Gymnasium "Aušra")

Medical education:

1976–1982 Kaunas University of Medicine, therapeutic faculty study

Study visits:

1999 traineeship at the Clinic of Children Diseases, Vilnius University, speciality of paediatric cardiologist (traineeship certificate No. 990006)

Work Experience:

1983–1988	Children outpatient clinic, Klaipėda, pediatrician.
1988–1992	Klaipėda City Hospital, neonatologist
1992–2009	Klaipėda Children Hospital, paediatric cardiologist,
2007–2009	Junior scientific assistant, Institute of Psychophysiology and Rehabilitation, Kaunas University of Medicine

Current positions:

Paediatric cardiologist, Klaipėda Children Hospital, Donelaičio 7, Klaipėda.
Junior scientific assistant, Institute of Psychophysiology and Rehabilitation, Kaunas University of Medicine, Vydūno 4, Palanga.

Professional qualification improvement:

1992	the second qualifying category of neonatologist granted (license number 91 2000 3637)
1994	the first qualifying category of pediatrician granted (license number 161-K)
1999	to practise paediatric cardiology (license number13141)
2004	to practise paediatric cardiology (license number MPL-04427)

Research investigation:

Assessment of the impact of the physical load on left ventricular morphometric and functional parameters in children and adolescents athletes.

Membership in professional organizations:

Since 2000	Member of Lithuanian Society of Pediatric Cardiology
Since 1998	Member of Lithuanian Heart Association
Since 1999	Member of Lithuanian Society of Cardiology
Since 1985	Member of Lithuanian Paediatric Association
Since 1989	Member of Lithuanian Medical Association
Since 1993	Member of Lithuanian Society of Rheumatologists
Since 2000	Member of Lithuanian Society of Cardiology, Klaipėda branch
Since 2007	Member of Association for European Paediatric Cardiology