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Echocardiographic evaluation of cardiovascular system in adolescent athletes in view of physiological adaptation to physical training

Echokardiograficzna ocena układu krążenia młodzieży uprawiającej sport wyczynowy w aspekcie rozwoju mechanizmów adaptacyjnych do wysiłku fizycznego

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Abstract

Introduction. Assessment of cardiovascular system in young athletes is a subject of active research. Cardiac morphology is difficult to evaluate due to significant anthropometric differences between individuals, especially during puberty and growth spurt.

The aim of this paper was an assessment of systematic physical training's impact on cardiovascular system and cardiac remodeling in young athletes.

Material and methods. Study involved 89 adolescent athletes, including 41 football players and tennis players (group 1) and 48 beginner rowers (group 2). All athletes included in the study underwent ergospirometric tests with evaluation of peak oxygen uptake (VO_2max) as well as a 12-lead electrocardiographic and echocardiographic evaluation.

Results. Athletes in group 1 (football/tennis players) were compared to group 2 (rowers). There were no significant differences in age (14.2 ± 1.1 vs. 14.3 ± 1.2 years, p = NS) or sex (6 [7.6%] vs. 8 women [10.2%], respectively, p = NS). Differences were observed in anthropometric parameters, cardiopulmonary fitness, and resting heart rate. Most parameters of cardiac morphology indexed to body area (indexed value: raw data/bodu surface area) were greater in group 1 (left ventricular end-diastolic dimension 29.1 ± 2.5 vs. 26.8 ± 2.7 mm/m^2, $p < 0.001$; septal thickness: 6.0 ± 0.7 vs. 5.4 ± 0.8 mm, p = 0.001; posterior wall thickness: 0.8 ± 0.6 vs. 5.2 ± 0.6, $p < 0.001$; proximal part of right ventricle outflow tract: 16.1 ± 2.2 vs. 14.5 ± 2.0 mm/m^2, p = 0.001; right ventricle inflow tract: 19.9 ± 2.1 vs. 18.5 ± 2.6 mm/m^2, p = 0.01). When allometric scaling was employed, most differences were insignificant, apart from indexed left ventricle mass (87.0 ± 13.9 vs. 76.8 ± 12.2 g/(m^2)$^{1.5}$, p = 0.001).

Conclusions. 1. Allometric indexation of echocardiographic parameters in young athletes is appropriate since relationship between body height increase and the rate of internal organ growth in these subjects is non-linear. 2. Even a short physical training in young athletes has impact on their condition but does not significantly affect parameters of cardiac morphology.

Key words: athlete's heart, adolescent athletes, echocardiography

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Introduction

Regular physical training causes important in adaptive changes in the heart. Physiological changes in cardiac morphology, and mechanical and electrophysiological function due to increased cardiovascular load are referred to as athlete's heart. Remodeling pattern depends mostly on type of training, and sport [1–5].

Morganroth et al. described two patterns of left ventricle remodeling: 1) concentric hypertrophy, and 2) eccentric hypertrophy. The former variant includes thickening of the left ventricle muscle with no influence on the chamber's cavity. This occurs mostly due to static activity (resistance training), with increased systemic arterial pressure leading to pressure overload. The latter variant, eccentric hypertrophy, results in increasing dimension of the heart cavity, and proportional thickening of its wall due to dynamic activity (endurance training), with increased cardiac output [6].

In real life, however, there are no purely static or purely dynamic activities, and both components can be identified in any type of physical activity or training. Based on proportions of the static and dynamic component of physical activity, Mitchell et al. [7] proposed a classification of nine groups of sports, which reflects total cardiovascular load. According to this system, class IIIC sports are characterized by high intensity of static exercise and high intensity of dynamic exercise, with accompanying high cardiovascular load. These sports include rowing, kayaking and cycling, among others [7].

Evaluation of adaptational changes in cardiovascular system in children and adolescent athletes is a subject of particular interest but also a major challenge. In these populations physical training, sometimes of very high intensity, affects body which is in the period of growth spurt and puberty. As maturation pace varies both between girls and boys but even between individuals of the same sex, anthropometric parameters (body height, body mass and body mass index, body surface area) may differ substantially in children of the same age, with similar differences in dimensions of internal organs including heart. Identifying features of heart remodeling due to physiological age-related body growth and maturation, and distinguishing them from training-induced adaptational changes may be therefore difficult.

In order to eliminate disproportions in heart cavity dimensions related to variation in anthropometric parameters, indexation of echocardiographic parameters to body surface area (BSA) is currently applied [8]. This modality is in routine use but some authors postulate that allometric scaling be used for children and adolescents, and for assessment of right ventricle parameters [9, 10].

At the same time, various cardiovascular diseases and anomalies may manifest or progress in young subjects. If not previously identified, these may pose a potential threat to young athletes' health or even become life-threatening [11–13].

The presented study addressed the following issues:
- screening of children and adolescents during the period of growth spurt and puberty for potential undetected cardiovascular diseases;
- impact of systematic training upon physical condition of young athletes, and evaluation of adaptational changes in cardiovascular system;
- evaluation of cardiovascular adaptation patterns in view of echocardiographic parameter indexation modality, i.e. indexation to BSA versus allometric scaling.

Material and methods

For initial phase of the study, 89 young athletes were recruited from sports clubs in Warsaw or Mazovian voivodeship. Physical examination was performed in all athletes, with evaluation of extended medical and family history (anamnestic data obtained from parents). Then, anthropometric studies were performed (body mass, body height, body fat measurement), followed by electrocardiographic (ECG) and echocardiographic studies. Of all evaluated subjects, 78 athletes were then qualified to the main study involving functional tests. These athletes were divided into two groups, which reflected sports they trained. Footballers and tennis players (group IC [acc. to Mitchell's classification of sports]) were included in group 1 (33 persons), and beginner rowers were included as group 2 in the study (sport class IIIC, 45 persons). Reasons for exclusion at this stage were the following: abnormalities detected during screening, which warranted further cardiovascular investigations (4 persons, these issues are further discussed under Results); physical injury (2 persons); and not following the previously outlined training program (5 persons).

Anthropometric and biometric studies

Body surface area was calculated using Mosteller formula involving body height and mass. The obtained BSA values were then applied for indexation of echocardiographic parameters concerning heart cavity dimensions [14].

Body fat and lean body mass were calculated using the TANITA body composition analyzer BC 418 (Tokyo, Japan).

Electrocardiographic studies

Twelve-lead electrocardiographic tests (ECG) were performed at rest, at least 12 hours after last training, using Marquette-Hellige device (Cardiosoft®, Cologne, Germany).

Echocardiographic studies

Echocardiographic studies (ECHO) were performed at rest, in left lateral decubitus position, using Vivid 7 device

(GE Vingmed Ultrasound AS, USA) with M4S transducer (1.5–4.0 MHz). Evaluation was performed using standard planes: parasternal (along short and long axis), apical (four-, two- and trichamber projection) as well as right ventricle projection. Images were recorded and analyzed using dedicated software (EchoPAC version 112, GE Vingmed Ultrasound AS, USA). Dimensions of heart chambers were measured according to current guidelines [8, 15].

Left ventricle mass was calculated using dimensions of left ventricle chamber and left ventricle end-diastolic wall thickness using Devereux formula [16].

Taking into account substantial differences in anthropometric parameters (including BSA), echocardiograhic parameters were indexed for BSA or allometrically scaled. Allometric scaling was applied because of the subjects' young age, in order to eliminate potential aberrations due to disproportional heart development as compared to rapidly growing body. Using literature references, allometric scaling was applied to left ventricle dimensions, mass and wall thickness as well as right ventricle dimensions [9]. No formulas are available for indexation of other parameters.

Ergospirometric tests

Ergospirometric tests for rowers were performed using the Concept2 rower device (Morrisville, USA), whereas football players and tennis players were tested using the cycle ergometer (Lode Excalibur Sport PFM 925900, Holland). Tests involved three-minute-long intervals of increasing power, pursued until the limit of participant's abilities. During the test, maximal oxygen consumption (VO_2max) was measured. Footballers and tennis players performed continuous tests, whereas had intervals separated by 30 second brakes. Continuous registration of gas exchange parameters was performed throughout the test, including tidal volume, and oxygen consumption (measured using the MetaLyzer 3B-R2 device, Cortex, Germany). Capillary blood samples were taken for measurement of lactate level (Super GL, Muller, Germany) during the break after each three-minute-long test interval in rowers or during the last 15 seconds of a three-minute-long interval in tennis players. Blood lactate concentration was then used for calculating anaerobic (lactate) threshold value, using the cut-off level of 4 mmol/l lactate (functional threshold power).

Bioethical approval

The study was accepted by the bioethical committee at the Institute of Sport in Warsaw. All participants and their parents/legal representatives gave informed written consent to participation in the study.

Statistical analysis

Statistical analyses were performed using the Statistica 10 software (StatSoft, Tulsa, OK, USA). Data were presented as mean values ± standard deviation (SD). Normal distribution of values was verified using Shapiro-Wilk test. For comparisons between the groups, Student's *t*-test or Mann-Whitney U test were used for quantitative variables, and χ^2 test for qualitative variables. The level of statistical significance was adopted at $p < 0.05$.

Results

No significant differences were observed between the groups as to the athletes' age and sex. Participants in group 1 were significantly shorter and lighter, which resulted in lower BMI and BSA values. Footballers and tennis players had lower body fat and lean body mass values but relative proportion of fatty tissue to overall body mass was similar in both groups. Systolic and diastolic arterial pressure was similar in both groups. Athletes of a longer training experience had a significantly lower baseline heart rate. Table 1 presents detailed characteristics of athletes in both groups.

Screening

Screening for cardiovascular abnormalities using echocardiography identified in one athlete bicuspid aortal valve, previously undetected. In athletes with bicuspid aortic valve, no stenosis or valve insufficiency was observed, and the subject had normal aortic dimensions. The athlete was then included into the main study. Resting ECG detected ventricular arrhythmia in one female rower, with single or paired extrasystole of QRS morphology, which pointed out to right ventricle outflow region as the source of aberration. This athlete was subjected to further detailed cardiological evaluations. In three other athletes, resting blood pressure values and their evolution during exercise suggested potential arterial hypertension, therefore further specialist tests were ordered. Anamnestic data revealed no cases of sudden cardiac deaths in young close family members of the athletes (grade I and II relatives, under 40 years of age).

Cardiopulmonary fitness evaluation

Ergospirometric tests revealed that subjects with longer training experience (group 1) had significantly higher values of indexed cardiovascular fitness parameters as compared to athletes who began their training only recently (group 2). Footballers and tennis players achieved functional threshold power at higher levels of exercise intensity (2.8 ± 0.4 vs. 2.4 ± 0.4 W/kg at 4 mmol/l lactate, $p < 0.001$) as compared to beginner rowers. More experienced athletes could achieve even a greater threshold power calculated for body mass (4.0 ± 0.4 vs. 3.2 ± 0.6 W/kg, $p < 0.001$), and had higher maximal oxygen consumption indexed to body mass (VO_2max: 54.9 ± 6.4 vs. 51.2 ± 8.0 ml/kg/min, $p = 0.03$). No significant differences were observed in absolute values of test results (Table 2).

Table 1. Baseline characteristics of athletes in study groups

Parameter	Footballers or tennis players (group 1), n = 33 Mean value (± SD)	Rowers (group 2), n = 45 Mean value (± SD)	p
Age (years)	14.2 (± 1.1)	14.3 (± 1.2)	NS
Girls, n [%]	6; (7.6%)	8; (10.2%)	NS
Body height [cm]	170.2 (± 9.0)	175.5 (± 10.0)	0.019
Body mass [kg]	56.4 (± 12.0)	67.3 (± 15.6)	0.001
BMI [kg/m^2]	19.2 (± 2.5)	21.7 (± 4.1)	0.001
BSA [m^2]	1.6 (± 0.2)	1.8 (± 0.2)	0.002
Body fat mass [kg]	9.0 (± 3.4)	12.5 (± 5.8)	0.002
Lean body mass [kg]	47.5 (± 9.6)	54.9 (± 11.2)	0.003
Body fat percentage [%]	15.6 (± 4.2)	17.8 (± 5.4)	NS
Lean body percentage [%]	84.4 (± 4.2)	82.2 (± 5.4)	NS
Systolic arterial pressure	123.9 (± 18.2)	125.0 (± 11.2)	NS
Diastolic arterial pressure	62.6 (± 6.04)	64.6 (± 10.2)	NS
Duration of training (months)	21.8 (± 6.9)	9.1 (± 7.6)	< 0.001
Resting heart rate (heartbeats/min)	62.8 (± 9.5)	68.8 (± 14.5)	0.03

SD — standard deviation; NS — not statistically significant; BMI — body mass index; BSA — body surface area

Table 2. Ergospirometric test results in two study groups

Parameter	Footballers and tennis players (group 1), n = 33 Mean value (± SD)	Rowers (group 2), n = 45 Mean value (± SD)	p
Functional threshold power [W]	162.0 (± 37.0)	164.6 (± 39.7)	NS
Functional threshold power/body mass [W/kg]	2.8 (± 0.4)	2.4 (± 0.4)	< 0.001
Maximal exercise power [W]	236.5 (± 53.0)	221.0 (± 52.1)	NS
Maximal exercise power/body mass [W/kg]	4.0 (± 0.4)	3.2 (± 0.6)	< 0.001
VO_2max [l/min]	3.2 (± 0.7)	3.5 (± 0.7)	NS
VO_2max/body mass [ml/kg/min]	54.9 (± 6.4)	51.2 (± 8.0)	0.03
Maximal heart rate [beats/minute]	197.3 (± 7.9)	194.4 (± 7.6)	NS
Maximal lactate level [mmol/l]	10.1 (± 2.2)	9.3 (± 2.1)	NS

SD — standard deviation; W — watt; NS — not statistically significant; VO_2max — maximal oxygen consumption

Echocardiographic studies

Echocardiographic studies revealed no statistically significant differences in left ventricle mass or in non-indexed morphological parameters describing heart chambers and ascending aorta (table 3, non-indexed values). When anthropometric differences between the groups were taken into account, and indexation for BSA applied (Table 3, BSA indexed values), athletes having a longer training experience (footballers and tennis players) turned out to have a significantly thicker end-diastolic left ventricle chamber dimension and wall thickness as compared to beginner rowers. Chambers of the right heart in group 1 demonstrated a significantly greater dimension of the proximal part of right ventricle outflow tract, greater inflow tract dimension, right ventricle was longer and area of right atrium was greater.

Calculations performed with allometric scaling (Table 3, allometric scaled values) did not confirm previously mentioned differences in dimensions of right and left heart ventricles. Significant difference was, however,

Table 3. Echocardiographic measurement of heart chambers, left ventricle mass and diameters — absolute values, BSA-indexed values and allometric scaled values

	Non-indexed values			BSA-indexed values			Allometric scaled values			
	Footballers and tennis players (group 1) n = 33 Mean value (± SD)	Rowers (group 2) n = 45 Mean value (± SD)	p	Footballers and tennis players (group 1) n = 33 Mean value (± SD)	Rowers (group 2) n = 45 Mean value (± SD)	p		Footballers and tennis players (group 1) n = 33 Mean value (± SD)	Rowers (group 2) n = 45 Mean value (± SD)	p
Left ventricular mass [g]	182.6 (± 52.3)	188.0 (± 50.1)	NS	110.9 (± 21.1)	103.0 (± 18.0)	NS	LV mass $[mm/(m^2)]^{1.5}$	87.0 (± 13.9)	76.8 (± 12.2)	0.001
LVDd [mm]	46.8 (± 4.4)	47.8 (± 4.3)	NS	29.1 (± 2.5)	26.8 (± 2.7)	< 0.001	LVDd $[mm/(m^2)^{0.46}]$	37.5 (± 2.3)	36.5 (± 2.3)	NS
IVSDd [mm]	9.6 (± 1.2)	9.6 (± 1.0)	NS	6.0 (± 0.7)	5.4 (± 0.8)	0.001	IVSDd $[mm/(m^2)^{0.5}]$	7.2 (± 0.7)	7.5 (± 0.8)	NS
PWDd [mm]	9.4 (± 1.3)	9.3 (± 1.4)	NS	5.8 (± 0.6)	5.2 (± 0.6)	< 0.001	PWDd $[mm/(m^2)^{0.5}]$	7.0 (± 0.8)	7.3 (± 0.8)	NS
LAA $[cm^2]$	18.6 (± 3.0)	19.5 (± 3.4)	NS	11.5 (± 1.4)	10.9 (± 1.9)	NS	–	–	–	–
Ao asc [mm]	22.7 (± 2.3)	23.4 (± 2.4)	NS	14.1 (± 1.7)	13.1 (± 1.7)	0.02	–	–	–	–
RVOTprox [mm]	25.8 (± 2.6)	25.9 (± 3.3)	NS	16.1 (± 2.2)	14.5 (± 2.0)	0.001	RVOTprox $[mm/(m^2)^{0.311}]$	22.2 (± 2.1)	21.6 (± 2.4)	NS
RVD1 [mm]	32.0 (± 3.3)	33.0 (± 3.2)	NS	19.9 (± 2.1)	18.5 (± 2.6)	0.01	RVD1 $[mm/(m^2)^{0.468}]$	25.6 (± 2.0)	25.1 (± 2.3)	NS
RVD2 [mm]	24.1 (± 3.4)	25.4 (± 2.9)	NS	14.9 (± 1.7)	14.2 (± 1.9)	NS	RVD2 $[mm/(m^2)^{0.5}]$	18.9 (± 2.1)	18.9 (± 2.0)	NS
RVD3 [mm]	71.5 (± 7.1)	73.2 (± 7.4)	NS	44.5 (± 4.5)	41.1 (± 5.5)	0.006	RVD3 $[mm/(m^2)^{0.3666}]$	60.0 (± 4.6)	59.1 (± 5.4)	NS
RAA $[cm^2]$	15.0 (± 2.3)	15.2 (± 2.9)	NS	9.3 (± 1.0)	8.5 (± 1.5)	0.01	–	–	–	–

BSA — body surface area; SD — standard deviation; NS — not statistically significant; LV — left ventricle; LVDd — left ventricular end-diastolic diameter; IVSd — interventricular septum end-diastolic diameter; PWDd — posterior ventricular wall end-diastolic diameter; LAA — left atrium area; Ao asc — diastolic dimension of ascending aorta; RVOTprox — right ventricular outflow tract diameter, proximal part; RVD1 — right basal ventricular diameter (inflow tract); RVD2 — right mid-ventricular diameter; RVD3 — right ventricular diameter base to apex; RAA — right atrium area observed in left ventricle mass, which was greater in athletes of longer training experience (87.0 ± 13.9 vs. 76.8 ± 12.2, $p = 0.001$). Thickness of ventricle walls was similar in both groups. The recorded values of ventricle wall thickness in footballers and tennis players as compared to rowers were the following: interventricular septum 7.2 ± 0.7 vs. 7.5 ± 0.8 mm/$(m^2)^{0.5}$ ($p = 0.08$), and posterior wall 7.0 ± 0.8 vs. 7.3 ± 0.8 mm/$(m^2)^{0.5}$ ($p = 0.07$).

Discussion

Presented results contribute to knowledge of exercise physiology in adolescent athletes (between 13–17 years of age) who are at the beginning of their sports career. This group of sportsmen is most seldom studied, with only anecdotal reports on morphological adaptation o the heart to regular physical training. The value of this study is homogenous composition of the analyzed athlete population in view of the sporting disciplines (category IC [acc. to Mitchell's classification]). Screening phase of the study identified single subjects with cardiovascular aberrations, which necessitated further diagnostics. This emphasizes the need of scrupulous investigation of young persons qualified as potential professional athletes. That issue is of particular importance at the beginning of athletic career, when severe cardiovascular complications are relatively often encountered, and the necessity of redirecting of the young person's future plans (including giving up professional sport, in extreme situations) is least dramatic [11–13].

The study shows that even a short period of systematic physical exercise contributes to a marked improvement in general cardiovascular fitness of the individual. Athletes having a longer training experience were able to perform more intensive physical exercise, had higher maximal oxygen consumption, and entered the anaerobic phase at higher levels of physical exercise power. They demonstrated also lower baseline heart rate, which is a physiological attribute of the so-called athlete's heart. Results of the study prove that regular endurance training improves physical capacity, which is the key factor in cardiovascular fitness, and the future health state [17].

Echocardiographic measurement of morphological parameters used to describe morphological changes in heart in response to physical training gave different results depending on how the data was presented. There were no differences in absolute values of the above mentioned parameters between football players/tennis players and rowers but the two groups demonstrated important differences in anthropometric characteristics (body height, body weight, BSA). This finding necessitated indexation of echocardiographic readings, in line with current praxis. Classical indexation to BSA produced significant differences in most parameters concerning right heart chambers as well as diameters and thickness of left ventricle. These values were significantly higher in athletes having a longer training experience, which suggests that professional physical training, albeit of short duration, has impact on heart morphology. Single reports can be found in literature concerning heart remodeling under physical training in the same age group as here presented. These reports show contradictory results but the uniform general conclusion is that physical training almost always results in left ventricle remodeling in adolescents, although to a different extent [18–22].

Sharma et al. [20] also reported a greater wall thickness and a greater end-diastolic diameter of left ventricle in junior athletes as compared to their not physically active peers. Left ventricle mass and left atrium areas were also greater in the cited report, which was not the case in our study. However, the athlete population described herein (footballers and tennis players) was younger, had a shorter training experience, and both sports belonged to the same category. Sharma and colleagues, on the other hand, evaluated athletes representing various sporting disciplines, including the ones with maximal static exercise component [20].

Another report compared adolescent football players with a control group, demonstrating a greater indexed left ventricle mass in athletes but showing no difference in BSA-indexed dimensions and thickness of this ventricle. Authors of this study compared also tennis players to control group but found no differences in the analyzed parameter values. However, no detailed information was provided on duration of training in the analyzed athlete groups [22].

One more study by Sharma and colleagues analyzed black adolescent athletes (mean age of 16.4 ± 1.3 years), and compared them to a control group of non-physically active peers (15.4 ± 1.3 years). Subjects in the study group had a significantly greater left ventricle mass but no such difference was found in maximal and relative left ventricle thickness. White (Caucasian) athletes were analyzed as a separate subgroup, and compared to the control group too. These were found to have a greater indexed left ventricle mass and lesser relative left ventricle diameter as well, whereas difference in maximal indexed left ventricle thickness was not significant as compared to control group. In the cited study, however, no data was provided on dimensions of the right heart chambers or indexed parameters of left ventricle chamber, and both studied groups had significantly different BSA values [21]. Given different character of adaptational mechanisms in black and Caucasian athletes, it is difficult to compare these results with the presented study [23, 24].

Most published reports concerning the right heart morphology concern adult athletes [25, 26], and hardly any publications on this issue can be found describing potential adaptational changes in adolescent sportsmen.

In the presented study, BSA-indexation provided significant differences in right atrium area and almost all parameters describing the right ventricle dimensions. This can point to right ventricle remodeling under conditions of physical training, occurring already in young sportsmen. On the other hand, the population we studied included athletes in the period of their most dynamical development phase. Increasing body mass and body weight may have different pace in various individuals, and show non-linear correlation to development of internal organs, including the heart. In this case, allometric scaling seemed most appropriate, as this method aims to eliminate developmental non-linearity between anthropometric parameters and heart dimensions. Some authors postulate allometric scaling in all age groups, especially when evaluating the right ventricle chamber [10]. In the presented study, allometric scaling eliminated the previously observed differences in right ventricle diameters, left ventricle end-diastolic diameter and wall thickness. However, a statistically significant difference in left ventricle mass could be observed, and the parameter had a markedly greater value in athletes having a longer experience in training. Isolated greater mass but no differences in diameters and wall thickness of the left ventricle may be surprising, especially when observed in athletes practicing sports from the IC category.

The results are in part compatible with other publications, where greater left ventricle mass but no difference in chamber dimensions was observed after allometric scaling in athletes practicing mostly dynamic sports (football, volleyball, basketball, and handball) as compared to control group [19]. These observations concerned however much older sportsmen (19–30 years of age) than in our study, which is the strength of the presented publication.

On the other hand, even a minor increase in left ventricle muscle thickness and dimensions of the chamber results in a significant increase in left ventricle mass [27]. In the presented study, significant difference was observed in ventricle mass but not in other analyzed parameters, probably due to young age of the athletes.

Limitations of the study

The authors believe that the main limitation of the study was the fact that control group did not consist of non--physically active persons but of beginner rowers. This could have eliminated intergroup differences to some extent. However, important differences could be observed in cardiovascular fitness, resting heart rate, and BSA-indexed diameters of heart chambers. A different choice of control group subjects might have contributed to many statistically significant differences in the analyses.

Summary

Relatively short period of regular physical training in adolescent athletes contributes to improved general cardiovascular fitness, and results in initiation of morphological adaptation to physical exercise. Impact of sporting activities in young athletes remains only partly understood, as results differed markedly depending on the applied indexation method. Allometric scaling may become a more appropriate modality of indexing echocardiographic parameter values in adolescent athletes who demonstrate prominent differences in biometric parameters between individuals. However verification in a bigger group of sportsmen is warranted.

Conclusions

1. Allometric scaling of echocardiographic parameter values in adolescent sportsmen seems warranted, as rate of body height and development of internal organs demonstrate a non-linear relationship in this age group.
2. Physical training, even if of short duration, markedly improves physical capacities in adolescent subjects, with no significant impact on most morphological parameters of the heart.

Conflict of interest(s)

None declared.

Streszczenie

Wstęp. Ocena układu krążenia u młodych sportowców pozostaje tematem aktywnych badań. Duże trudności pojawiają się w zakresie oceny wielkości i grubości jam serca ze względu na istotne różnice antropometryczne między poszczególnymi zawodnikami gdzie trening fizyczny (nierzadko bardzo intensywny) nakłada się na okres dojrzewania i szybkiego wzrostu.

Celem pracy była ocena wpływu regularnego wysiłku fizycznego na układ krążenia u dorastających sportowców.

Materiał i metody. W badaniu oceniano 89 sportowców — 41 jeden piłkarzy oraz tenisistów (grupa 1.) oraz 48 rozpoczynających karierę sportową wioślarzy (grupa 2.). U wszystkich kwalifikujących się zawodników wykonano badanie ergospirometryczne z oceną szczytowego pochłaniania tlenu (VO_2*max*) oraz badania elektrokardiograficzne i echokardiograficzne.

Wyniki. Porównano sportowców z obu grup, tj. piłkarzy i tenisistów (grupa 1.) z grupą wioślarzy (grupa 2.). Obie grupy nie różniły się wiekiem (14,2 ± 1,1 *v.* 14,3 ± 1,2 roku; p = NS) oraz płcią (dziewczęta: 6 [7,6%] *v.* 8 [10,2%]; p = NS]. Dłużej trenujący piłkarze i tenisiści, w porównaniu z grupą wioślarzy, różnili się pod względem parametrów antropometrycznych, parametrów wydolności fizycznej oraz spoczynkowej częstości rytmu serca. Większość wymiarów jam serca indeksowanych względem pola powierzchni ciała była większa w grupie osób dłużej trenujących piłkarzy i tenisistów (końcoworozkurczowy wymiar lewej komory: 29,1 ± 2,5 *v.* 26,8 ± 2,7 mm/m^2; p < 0,001; grubość przegrody międzykomorowej: 6,0 ± 0,7 *v.* 5,4 ± 0,8 mm; p = 0,001; grubość ściany tylnej: 0,8 ± 0,6 *v.* 5,2 ± 0,6; p < 0,001; proksymalny fragment drogi odpływu prawej komory: 16,1 ± 2,2 *v.* 14,5 ± 2,0 mm/m^2; p = 0,001; wymiar drogi napływu prawej komory: 19,9 ± 2,1 *v.* 18,5 ± 2,6 mm/m^2; p = 0,01). Po zastosowaniu indeksacji allometrycznej większość oberwanych różnic przestała mieć znaczenie istotne statystycznie, z wyjątkiem indeksowanej masy lewej komory (87,0 ± 13,9 *v.* 76,8 ± 12,2 g/(m^2)^{1,5}; p = 0,001).

Wnioski. 1. Zastosowanie indeksacji allometrycznej w stosunku do parametrów echokardiograficznych u dorastających sportowców wydaje się właściwe ze względu na nieliniową zależność pomiędzy tempem wzrostu, a szybkością zwiększania się narządów wewnętrznych w tej grupie wiekowej. 2. Nawet krótki trening fizyczny u dorastających sportowców ma istotny wpływ na poprawę parametrów wydolności fizycznej, bez znaczącego wpływu na większość parametrów morfologicznych serca.

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Komentarz

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Autorzy pracy pt. „Echocardiographic evaluation of cardiovascular system in adolescent athletes in view of physiological adaptation to physical training" objęli programem oceny kardiologicznej grupę młodych sportowców. Praca ta wypełnia lukę w zakresie opisu zmian strukturalnych i funkcjonalnych w układzie sercowo-naczyniowym młodych sportowców. Chociaż mamy świadomość zjawiska serca sportowca, to jednak problemy w diagnostyce różnicowej zmian adaptacyjnych w sercu w odpowiedzi na wysiłek nadal pozostają wyzwaniem klinicznym. Kolejną zmienną, którą powinniśmy uwzględnić w tym postepowaniu różnicowym, jest kwestia młodego wieku wielu sportowców, rozpoczynających kariery zawodnicze, krótszy czas trwania potencjalnej przebudowy serca u młodych zawodników oraz różnice w zakresie powierzchni ciała (BSA, *body surface area*) u dorastającej młodzieży sportowej.

Podstawowymi parametrami służącymi do oceny anatomicznych zmian u sportowców są wielkość i proporcje jam serca. Jako pierwszy odkrycia tego dokonał Henschen pod koniec XIX wieku podczas badania przedmiotowego za pomocą opukiwania klatki piersiowej narciarzy biegowych.

Dużą zaletą pracy, co świadczy o ugruntowanym doświadczeniu w wykonywaniu tego typu badań, jest wykorzystanie różnych ergometrów przeznaczonych do odpowiednich dyscyplin sportowych. Sportowców podzielono ze względu na uprawianą dyscyplinę sportową o różnej komponencie statycznej i dynamicznej, wyróżniając sporty IC, do których zaliczono piłkę nożną i tenis (grupa 1.) oraz sport IIIC, tj. wioślarstwo (grupa 2.). Ma to uzasadnienie w obserwacji o istniejącym związku między intensywnością i rodzajem wysiłku fizycznego a rozwojem serca sportowca, które wyraża się nie tylko powiększeniem sylwetki serca, ale również zmianami funkcjonalnymi. Na wspomnianą przebudowę wpływa wiele czynników — typ dyscypliny sportowej, czas trwania kariery sportowej, wiek, płeć, rasa, powierzchnia ciała, a także czynniki genetyczne. Atutem pracy jest skrupulatna analiza wyników z zastosowaniem indeksacji względem BSA oraz indeksacji allometrycznej, istotnej u młodych osób.

Obecnie wyróżnia się dwie formy sportowej przebudowy serca, tj. ekscentryczną i koncentryczną. U sportowców uprawiających dyscypliny sportowe z przewagą komponenty statycznej (tj. podnoszenie ciężarów, sporty walki, pchnięcie kulą) przebudowa serca ma charakter koncentryczny, a u sportowców uprawiających dynamiczne dyscypliny sportowe (tj. tenis ziemny, kolarstwo) przebudowa ma charakter bardziej ekscentryczny. W literaturze jest opisywana bardziej nasilona przebudowa serca u sportowców uprawiających dyscypliny, w których obie komponenty — statyczna i dynamiczna — są silnie wyrażone, na przykład u wioślarzy i kajakarzy. Wioślarze uzyskują również lepsze wyniki ergospirometryczne w zakresie szczytowego zużycia tlenu (VO_2*peak*). Obserwacjom tym przeczy ta praca, ponieważ grupę 2. stanowili wioślarze i to w niej zaobserwowano mniejsze zmiany fizjologiczne w odpowiedzi na wysiłek fizyczny, zarówno w obrazie echokardiograficznym, jak i badaniu ergospirometrycznym. Zjawisko to można tłumaczyć faktem krótkiego okresu kariery sportowej zawodników.

Stwierdzono większą masę lewej komory u sportowców dłużej trenujących. Grubość ścian była porównywalna we wszystkich grupach sportowców. Indeksacja allometryczna spowodowała niwelację różnic między badanymi grupami w zakresie parametrów echokardiograficznych opisujących wielkość jam serca i grubość jego ścian. Dłuższy okres kariery zawodniczej miał również przełożenie na lepsze wyniki funkcjonalne oceniane za pomocą sercowo-płucnego testu wysiłkowego.

Najważniejsze implikacje praktyczne wynikające z tej pracy odnoszą się do kwestii orzecznictwa w zakresie medycyny sportowej. Niebagatelne znaczenie ma konieczność różnicowania adaptacji serca w odpowiedzi na wysiłek u młodych sportowców rozpoczynających karierę zawodniczą z patologiami (kardiomiopatia przerostowa czy arytmogenna kardiomiopatia prawej komory), które stanowią główną przyczynę nagłych zgonów wśród sportowców.