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FEATURES OF CARDIAC REMODELING ASSOCIATED WITH SPORTS SPECIALIZATION IN ADOLESCENT ATHLETES

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Key words: cardiac remodeling, sports specialization, adolescent athletes, echocardiography, martial artists, cyclic and acyclic sports, correlation relationships.

Annotation. The article presents the indicators of echocardiographic examination of a sample of adolescent athletes (n=190) with sports experience from 3 to 5 years, which were differentiated by gender, age and orientation of sports. The features of cardiac remodeling in adolescents in groups of martial artists and representatives of cyclic and acyclic sports are shown. The features of cardiac remodeling, revealed in the examined adolescents, are the result of the manifestation of a complex of internal and external factors: the stage of ontogenetic development; the specificity of sports specialization; individual genetic profile of an athlete. The dominance of the influence of one of the factors or their combined effect determines the specificity of "age" and "sports" remodeling of the heart.

Introduction. One of the most important issues of sports and developmental physiology is a study of effect of systematic sports session on the morphofunctional state of the heart as a limiting organ of adaptive capabilities of the organism in whole. Intense development of children sports in Russia determines early sports specialization that sets an increase in training loads. Therefore, studies on effect of different factors of influence on the state of health of athletes, issues of selection into children sports schools and biomedical support of juniors become relevant [1-2]. Researchers started studying cardiac remodeling in recent years. It is also caused by an occurence of new methodological approaches to evaluating cardiac functions and introduction of modern methods of diagnosing various cardiovascular diseases.

The term “cardiac remodeling” means processes of structural and functional changes in the heart under the influence of internal and external factors. In foreign publications, cardiac remodeling is also described as the “cardiac syndrome of an athlete” [4]. Some researchers suggest differential diagnosis of the athlete’s heart and hypertrophic cardiomyopathy [5]. A number of athletes assume that athletes should be allocated to a separate group, and reference values of echocardiographic indicators,

i.e. markers of the “athletic heart”, which would define a border between adaptation and pathology, should be defined for them [6]. With the development in diagnostic capabilities and gathering new knowledge, researchers would suggest new criteria of pathological transformation of the cardiovascular system (CVS) in athletes [7].

The aim of this study was to reveal features of the structure and frequency of cardiologic morphofunctional changes, according to indicators of echocardiography among adolescent athletes of the Olympic reserve group, considering gender and sport specialization.

Methods and organization. The study was carried out at the preparatory stage of the training process. The sample included adolescent athletes with sports experience from 3 to 5 years, based on voluntary informed consent of participating in the study. General sample (n=190) was differentiated into groups of athletes of cyclic, acyclic sports and martial artists. Adolescent athletes of cyclic sports were divided into four subgroups, considering gender and age: young men of 13-15 years (n=19) and 16-18 years (n=22); young women of 13-15 years (n=34) and 16-18 years (n=16) respectively. Athletes of acyclic sports (n=40) were presented in a following way: young men aged 13-15 years (n=13) and 16-18 years (n=8); young women aged 13-15 years (n=13) and 16-18 years (n=6). Adolescent martial artists (n=59) were distributed accordingly: young men aged 13-15 years (n=24) and 16-18 years (n=19); young women aged 13-15 years (n=8) and 16-18 years (n=8).

Echocardiography (EchoCG) was made in horizontal position, after a 5-minute rest on the MINDRAY DC-6 device with a microconvex sensor 2P2 with a phased array (registration number: POCC CN IM41DO04379, registration certificate № FSZ 2011/09623). We kept to the EchoCG technique that was moderated by following documents: Recommendations for the quantitative assessment of the structure and function of the heart chambers (2006); Recommendations of European Echocardiography Association for standardizing indicators, digital storage and reporting of the study’s echocardiography (2008). We assessed following indicators: Simpson’s ejection fraction (EF, %), stroke volume (SV, ml), end-diastolic (EDD, cm) and end-systolic dimension (ESD, cm), left ventricle dimension, left atrium dimension (LA, cm), thickness of the interventricular septum (IS, mm), thickness of posterior wall of the left ventricle (PWLV, mm), diameter of aorta (AD, cm), pulmonary artery (cm), myocardium mass (g), e-point septal separation (EPSS, mm). Depending on the body surface area, we calculated indices of the end-diastolic dimension (EDDI, mm/m^2), myocardial mass index (MMI, g/m^2), as well as relative wall thickness (RWT, c.u.).

The statistical analysis of results was carried out using the IBM SPSS Statistics v. 23 package of application programs. To define differences in values of examined indicators from their normal distribution, we applied the Shapiro-Wilk

W-test. We used the Mann-Whitney U-test to check on statistical significance of received data. Study of correlation relationships was conducted with analysis of the Spearman's rank correlation coefficient. As a critical level of significance, we accepted the level of $p<0,05$. The obtained data in tables are presented in a form of medians, 25th and 75th centiles (Me; 25-75%).

Results and discussion. Table 1 presents median values of indicators of the EchoCG examination of adolescent athletes, specialized in cyclic sports and differentiated into gender and age. The analysis of EchoCG indicators in the age group of 13-15 years revealed statistically significant differences between young men and women in a number of indicators: ESD (U=194 when p=0,017); MMI (U=182,5 when p=0,009) and EPSSU=217,5 when p=0,044. Based on this tendency, differences were also registered in AD (U=227,5 when p=0,072). Differences between young men and women aged 16-18 years were revealed only in one indicator – EDD of LV (U=86 when p=0,008).

Table 1

EchoCG indicators of adolescent athletes of cyclic sports (Me (25-75%))

Parameter, unit of measurement	Young men		Young women	
	13-15 (n=19)	16-18 (n=22)	13-15 (n=34)	16-18 (n=16)
LA dimension, cm	3,22 (2,90-3,59)	3,09 (2,80-3,58)	3,10 (2,70-3,25)	3,25 (2,78-3,51)
EDD of LV, cm	4,80 (4,47-5,30)	5,08 (4,80-5,41)	4,55 (4,23-4,99)	4,40 (4,06-4,86)
ESD of LV, cm	2,20 (2,00-2,84)	2,20 (2,00-2,88)	1,75 (1,40-2,35)	2,22 (1,50-2,49)
EF, %	68,00 (65,00-78,50)	73,50 (66,50-79,00)	75,50 (66,00-85,75)	70,50 (66,00-74,50)
FS, %	38,00 (35,50-44,00)	40,50 (34,75-54,75)	45,50 (36,00-72,00)	39,50 (35,25-55,50)
AD, cm	2,13 (2,00-2,28)	2,00 (1,93-2,32)	2,00 (1,96-2,10)	2,05 (1,93-2,31)
PAP, cm	1,82 (1,70-1,91)	1,90 (1,80-2,00)	1,88 (1,73-2,00)	1,78 (1,70-1,98)
MM, g	147,00 (112,00-170,00)	145,00 (105,75-190,25)	103,00 (82,00-133,75)	115,50 (77,25-152,25)
RWT of LV, c.u.	86,00 (68,50-100,00)	86,00 (59,50-103,75)	66,50 (52,25-83,00)	81,00 (67,25-97,50)
EPSS, mm	0,34 (0,21-0,40)	0,35 (0,23-0,46)	0,30 (0,24-0,42)	0,36 (0,29-0,44)
EDDI, c.u.	3,00 (2,00-4,50)	3,00 (2,00-5,00)	3,50 (3,00-5,70)	3,00 (2,75-5,00)
SV, ml	27,61 (24,98-31,08)	27,14 (24,24-28,72)	28,57 (25,72-31,97)	27,50 (26,01-29,71)

Note: level of differences' significance: * – in age group between young men and women; + – between young women of compared age groups of 13-15 and 16-18 years; between young men of different age groups; FS – fractional shortening; AD – artery diameter; PAP – pulmonary artery pressure

EchoCG indicators of young athletes of acyclic sports are presented in table 2.

Table 2

EchoCG indicators of young athletes, engaged in acyclic sports (Me (25-75%))

Parameter, unit of measurement	Young men		Young women	
	13-15 (n=13)	16-18 (n=8)	13-15 (n=13)	16-18 (n=6)
LA dimension, cm	2,56 (2,0-3,0)	2,70 (2,05-2,90)	2,89 (2,70-3,20)	2,45 (2,25-2,95)
EDD of LV, cm	4,50 (3,90-5,00)	4,80 (4,23-5,20)	4,40 (4,00-4,70)	3,75 (3,63-4,03)
ESD of LV, cm	1,70 (1,50-2,10)	1,50 (1,20-1,63)	1,50 (1,30-1,70)	1,40 (1,40-1,48)
EF, %	66,00 (64,00-70,00)	74,50 + (72,00-78,75)	68,00 (68,00-72,00)	76,00 + (75,00-77,75)
FS, %	34,00 (33,00-36,00)	44,50 + (36,00-58,50)	35,00 (32,00-37,00)	42,00 (34,50-44,25)
AD, cm	1,80 (1,30-1,90)	1,65 (1,50-1,78)	1,80 (1,60-1,94)	1,85 (1,63-2,00)
PAP, cm	1,54 (1,45-1,73)	1,70 (1,59-4,60)	1,90 * (1,70-1,90)	1,90 (1,65-2,00)
MM, g	67,00 (54,00-94,00)	80,00 (70,75-126,75)	86,00 (66,00-95,00)	68,00 (65,5-96,75)
RWT of LV, c.u.	0,23 (0,20-0,31)	0,26 (0,24-0,31)	0,27 (0,24-0,40)	0,37 (0,30-0,40)
EPSS, mm	5,00 (4,00-5,00)	5,00 (4,00-6,00)	5,00 (3,00-6,00)	4,00 (2,25-5,00)
EDDI, c.u.	31,51 (27,86-33,96)	26,42 + (25,32-29,18)	28,57 (26,47-31,91)	24,70 (23,89-32,92)
SV, ml	39,00 (33,00-46,00)	56,00 + (48,50-74,00)	45,00 (40,00-51,00)	42,50 (27,25-45,75)

Note: level of differences' significance: * – in age group between young men and women; + – between young women of compared age groups of 13-15 and 16-18 years; between young men of different age groups; FS – fractional shortening; AD – artery diameter; PAP – pulmonary artery pressure

According to EchoCG indicators between young men of different age groups, we discovered differences in following parameters: EF, % (U=10,5 при p=0,003); FS, % (U=15,5 when p=0,008); PAP, cm (U=28 when p=0,08); EDDI, c.u. (U=21 when p=0,025); SV, ml (U=17 when p=0,011).

Between young women of both compared age groups, only one difference was registered – in EF, % (U=16,5 when p=0,047).

Data from table 2 indicate a presence of statistically significant gender differences in the age group of 13-15 years between young men and women, engaged in acyclic sports, in PAP, cm (U=43 when p=0,032). Differences in the age group of 16-18 years between young boys and girls were revealed in following parameters: EDD of LV, cm (U=9,5 when p=0,061), RWT of LV, c.u. (U=11 when p=0,093), SV, ml (U=11 when p=0,093).

Table 3 presents EchoCG parameters of young athletes, engaged in martial arts.

Table 2

EchoCG indicators of young athletes, engaged in martial arts (Me (25-75%))

Parameter, unit of measurement	Young men		Young women	
	13-15 (n=24)	16-18 (n=19)	13-15 (n=8)	16-18 (n=8)
LA dimension, cm	2,70 (2,48-3,30)	2,70 (2,40-2,85)	2,85 (2,68-3,35)	3,10* (2,98-3,45)
EDD of LV, cm	4,85 (4,33-5,20)	5,20 (4,80-5,70)	4,50 (3,95-5,13)	4,35* (4,23-4,83)
ESD of LV, cm	1,95 (1,68-2,23)	2,00 (1,80-2,30)	1,60 (1,30-1,90)	1,75 (1,08-1,98)
EF, %	69,50 (66,50-75,00)	72,00 (65,50-81,50)	81,00 (68,25-88,00)	70,15 (67,25-77,75)
FS, %	36,45 (30,00-42,25)	58,00 + (35,5-72,00)	63,00 (35,5-64,5)	42,50 (37,43-61,75)
AD, cm	1,80 (1,38-2,01)	2,00 (1,70-2,05)	2,00 (1,98-2,00)	2,00 (1,98-2,03)
PAP, cm	1,60 (1,60-1,90)	1,70 (1,60-1,90)	1,80 (1,73-2,00)	1,90 (1,80-2,00)
MM, g	90,00 (74,00-96,25)	104,00 + (92,50-124,00)	74,50 (54,50-105,25)	94,00 (78,75-101,75)
RWT of LV, c.u.	0,25 (0,20-0,33)	0,22 (0,21-0,35)	0,28 (0,25-0,30)	0,29 (0,28-0,31)
EPSS, mm	5,00 (3,75-6,00)	6,00 (4,50-6,00)	3,50 (2,75-5,00)	3,50 (2,00-5,85)
EDDI, c.u.	31,89 (27,63-34,34)	29,59 (26,30-31,22)	29,70 (27,89-32,00)	28,35 (25,57-30,20)
SV, ml	45,50 (34,50-62,25)	60,00 (43,00-79,00)	56,50 (38,50-61,00)	50,00 (39,50-57,50)

Note: level of differences' significance: * – in age group between young men and women; + – between young women of compared age groups of 13-15 and 16-18 years; between young men of different age groups; FS – fractional shortening; AD – artery diameter; PAP – pulmonary artery pressure

According to data, presented in the table, there were differences between young men of compared age groups of 13-15 and 16-18 years in following parameters: FS, % (U=124,5 when p=0,011), MM, g (U=127 when p=0,013). Differences in SV, ml did not reach statistical significance (U=157,5 when p=0,085).

There were no differences in EchoCG parameters in young women of compared age groups of 13-15 and 16-18 years. We also did not reveal statistically significant differences in the age group of 13-15 years between young men and women. It is to be noted that there were differences in FS (U=53,5 when p=0,064).

Differences between young men and women in the age group of 16-18 year old athletes were discovered in a number of parameters: LA dimension (U=25,5 when p=0,007), EDD of LV, cm (U=30 when p=0,014). According to the tendency,

differences were also found in following indicators: LA diameter (U=40,5 when p=0,057) and RWT of LV, c.u. (U=44,5 when p=0,093).

Then we analyzed EchoCG indicators (we took into account statistically significant differences) when comparing young men and women aged 13-15 and 16-18 years – athletes of different groups of sports specialization. Results are presented on figures 1 and 2.

The comparative analysis of measured EchoCG parameters in each group of young men and women, specialized in different sports, revealed a number of features:

- regardless of gender, there is a prevalent number of significant differences in EchoCG parameters of the heart between athletes of cyclic and acyclic sports, as well as between young male athletes who engage in cyclic sports and martial arts;

- in the group of young men, between athletes of cyclic and acyclic sports, among 11 significant differences in EchoCG parameters, only 6 remain in the older group. Differences in PWLV, IS, FS, SV, EDDI and PAP reduced. Among 8 differences in EchoCG indicators between athletes of cyclic sports and martial artists aged 13-15 years, we revealed differences in only 3 parameters in the older group. Between martial artists and athletes of acyclic sports of the younger group, there were no differences. In the older group, differences were found in ESD.

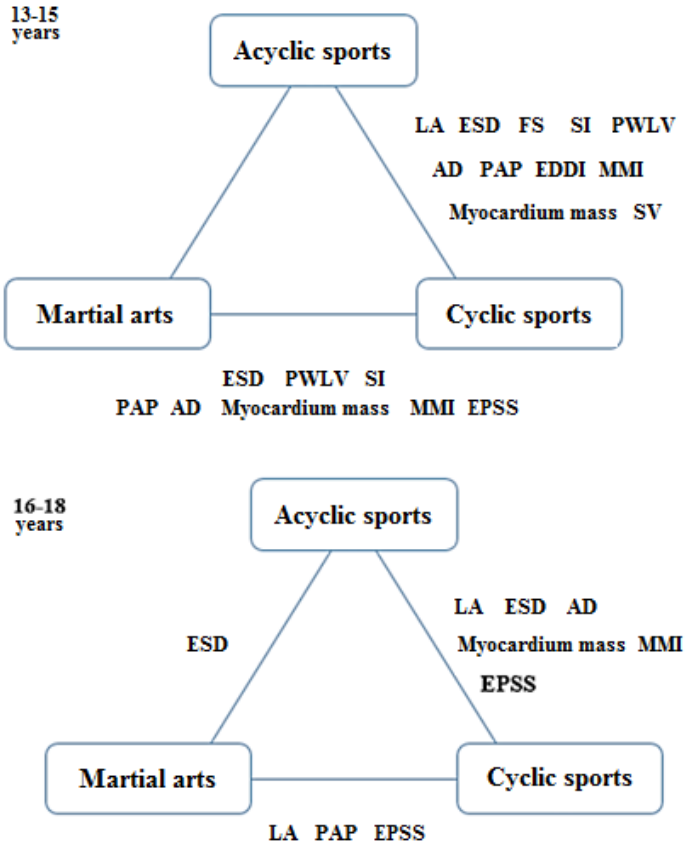

Fig. 1. EchoCG indicators of young male athletes aged 13-15 and 16-18 years – representatives of different groups of sports specialization

Among young female athletes of cyclic and acyclic sports, in the group of 13-15 years, we found differences in five parameters, in the older group there were differences in LA dimension (between athletes of acyclic and cyclic sports, athletes of acyclic sports and martial artists), in MMI – between athletes of cyclic sports and martial artists.

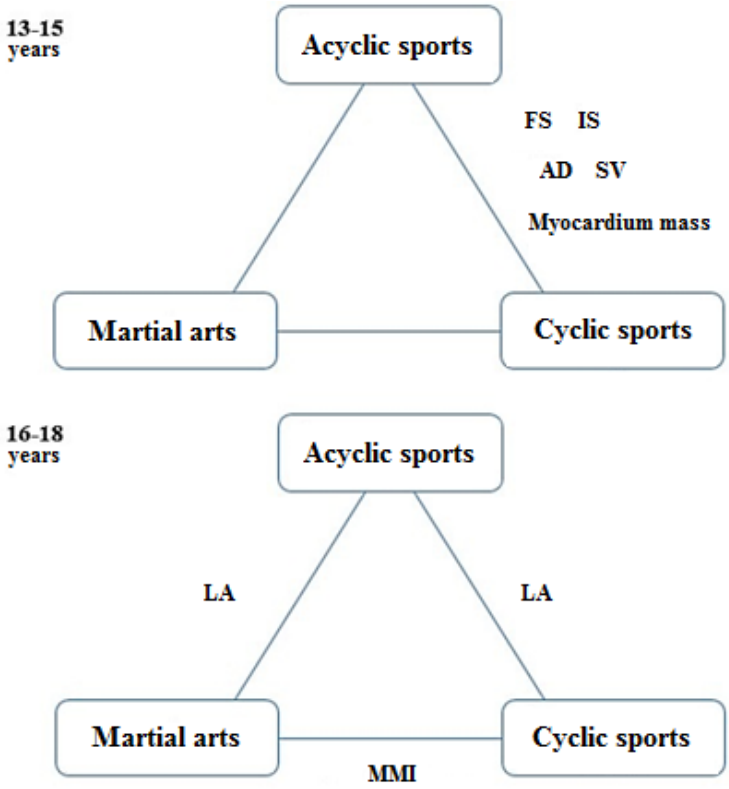

Fig. 2. EchoCG indicators of young female athletes aged 13-15 and 16-18 years – representatives of different groups of sports specialization

It is known that cardiac remodeling, caused by systematic and regular performance of physical loads, is characterized by structural changes in the heart, including hypertension of the left ventricle with a specific "sports geometry" (eccentric or concentric). The related changes of both systolic and diastolic functions become accepted components of cardiac remodeling [9].

When evaluating the functional state of the cardiovascular system in athletes, issues, related to a choice of appropriate indicators and their interpretation regarding representatives of sports specialization, remain unsolved. For example, features of morphometric indicators of the heart, types of remodeling young swimmers [10] and representatives of other specializations, remain insufficiently studied. Regular, many-hour physical loads influence the formation of myocardial remodeling in young athletes. When observing 60 young hockey players of the Children Sports School of the Olympic Reserve "Salavat Yulaev" located in the Republic of Bashkortostan, researchers found that a quarter (23,3%) of them had a moderate hypertrophy of the left ventricle's myocardium, which corresponds with signs of the

physiologically athletic heart. The pathological heart transformation in a form of eccentric hypertrophy of the myocardium and manifestation of diastolic dysfunction of the left ventricle was found in one athlete only [11].

Character of remodeling shows an objective total evaluation of the heart's state. In young athletes of game sports (soccer and hockey), cardiac remodeling was registered in 51,6% of cases, which indicates early adaptation to high loads. The most frequent option of remodeling is eccentric hypertrophy that points out combined loads on the heart with volume and pressure [12]. Structural remodeling of the heart is closely related to direction of the training process [13]. In case of endurance loads, eccentric remodeling occurs (with an increase of diastolic dimension of the left ventricle), in case of static loads – concentric (diastolic dimension of the left ventricle slightly changes).

In the work of G. McClean et al. (2018), age of a young athlete serves as a predictor of an internal diameter of the left ventricle during diastole, thickness of the interventricular septum during diastole, relative wall thickness and the left ventricle mass. The aforementioned indicators are higher in young male athletes than in young female athletes.

Covariance analysis with age, body surface area, systolic blood pressure, heart rate and gender as covariates revealed that gender is a leading predictor in identifying mass of the left ventricle, maximum wall thickness and end-diastolic dimension of the left ventricle [15]. Researchers established that gender, regardless of age, is a strong factor that defines structural parameters even in athletes of early adolescent age.

Portuguese scientists revealed that in adolescent basketball and hockey players, a diameter of the left atrium is statistically higher than in judokas. Thickness of the interventricular septum and thickness of the posterior wall of the left ventricle is lower in judokas than in athletes of other sports. Moreover, relative wall thickness of the left ventricle in swimmers is less than in judokas [16].

According to data given by A. D'Andrea et al. (2017), two types of directed training (for endurance and strength) that differently influence cardiac remodeling, implementing different scenarios of the heart's adaptation to specific physical loads [17].

It was also established that process of the myocardium hypertrophy is intensely developing mainly during the initial period of adaptation to specific physical loads. Results of adaptive compensatory rearrangements is a formed option of the heart's adaptation that insufficiently changes in the future. It was shown in works of N.D. Graevskaya et al. (1978).

Therefore, maximal morphological changes in the heart, associated with a type of sports, are shown in the age group of 13-15 year old athletes. In the group of

16-18 years, remodeling processes are less pronounced, according to a number of EchoCG parameters in particular.

Conclusion. As a result of the conducted analysis of EchoCG indicators, following features of cardiac remodeling were discovered in adolescent athletes:

– in groups of young men, maximal number of differences in indicators of the left atrium and left ventricle remodeling was found at the age of 13-15 years between athletes of cyclic and acyclic sports, athletes of cyclic sports and martial artists. In the group of 16-18 years, differences in IS, PWLV, FS and SV reduce between athletes of cyclic and acyclic sports, between athletes of cyclic sports and martial artists – in IS, PWLV, MM and MMI.

– in groups of young women, a number of differences in indicators of the left ventricle remodeling at the age of 13-15 years is twice less than in young men between athletes of cyclic and acyclic sports. There are no differences between athletes of cyclic sports and martial artists, athletes of acyclic sports and martial artists. In the group of 16-18 years, all differences reduced, except a difference in LA dimension between athletes of cyclic and acyclic sports, athletes of acyclic groups and martial artists, as well as the difference in MMI between athletes of cyclic sports and martial artists.

The revealed features of cardiac modeling in examined adolescents are the results of a whole set of factors: firstly – the stage of ontogenetic development, secondly – the specificity of sports specialization, thirdly – individual genetic profile of an athlete. Dominant influence of one of these factors or their combined effect defines specificity of "developmental" and "sports" cardiac remodeling.

One of the main factors of forming direction of cardiac remodeling is an individual genetic profile of athletes. In this case, the prospective studies would be studies on processes of cardiac remodeling, associated with gene polymorphisms that control the morphofunctional state of the cardiovascular system.

References

1. Balykova L.A. The use of derinate in comprehensive rehabilitation of children athletes / L.A. Balykova, E.N. Kaplina, S.A. Ivjanskij, O.V. Ferrapontova, N.V. Shchekina // Fundamental Research. – 2011. – № 10-2. – P. 265-269.

2. Shibkova D.Z. Selection and biomedical support for gifted children simultaneously involved in education and sports / D.Z. Shibkova, P.A. Bajguzhin, V.V. Erlikh, A.E. Batueva, E.S. Sabir'yanova // Science for Education Today. – 2020. – Vol. 10. – № 5. – P. 196-210. DOI: 10.15293/2658-6762.2005.11.

3. Talibov A.Kh. Predictors of cardiac remodeling and functional state of the cardiovascular system of athletes / A.Kh. Talibov // Physical Education and Sports Training. – 2018. – Vol. 1(23). – P. 71-82.

4. Kreso M. Athlete’s heart syndrome and echocardiographic changes / M. Kreso, A. Arslanagic // Bosnian journal of basic medical sciences. – 2008. – Vol. 8(2). – P. 116-120.

5. Sharma S. Physiologic limits of left ventricular hypertrophy in junior elite athletes: Relevance to differential diagnosis of athlete’s heart and hypertrophic cardiomyopathy / S. Sharma, B.J. Maron, S. Firoozi, P.M. Elliott, W.J. McKenna // J. Amer. Coll. Cardiology. – 2002. – Vol. 40(8). – P. 1431–1436. DOI: 10.1016/ s0735-1097(02)02270-2.

6. Gorbenko A.V. Physiological or pathological hypertrophy of athlete’s heart syndrome / A.V. Gorbenko, Yu.P. Skirdenko, N.A. Nikolaev, O.V. Zamahina, S.A. Sherstyuk, A.V. Ershov // Circulation Pathology and Cardiac Surgery. – 2020. – Vol. 24(2). – P. 16-25. DOI: 10.21688/1681-3472-2020 -2-16-25.

7. Ivyanskij S.A. Current aspects of cardiac remodeling in young athletes / S.A. Ivyanskij, L.A. Balykova, A.N. Urzyaeva, N.V. Shchyokina // Science and Sports: Modern Tendencies. – 2013. – № 1(1). – P. 80-88.

8. Shiller N.B. Clinical echocardiography / N.B. Shiller, M.A. Osipov // M.: MEDpress-inform. – 2018. – 344 p.

9. Weiner R.B. Exercise-induced cardiac remodeling / R.B. Weiner, A.L. Baggish // Prog Cardiovasc Dis. – 2012. – Vol. 54 (5). – P. 380-386. DOI: 10.1016/j.pcad.2012.01.006.

10. Malakh O.N. Morphometry indicators of the left ventricle of young swimmers regarding sports qualification and training process direction / O.N. Malakh // Science and Sports: Modern Tendencies. – 2015. – Vol. 8(3). – P. 70-74.

11. Yumalin S.Kh. State of the myocardium in young athletes according to echocardiography / S.Kh. Yumalin, L.V. Yakovleva, R.M. Kofman // Modern Problems of Science and Education. – 2014. – Vol. 3. – P. 447.

12. Sharykin A.S. Cardiac remodeling options in children and adolescents in playing sports (on the example of soccer and hockey) / A.S. Sharykin, Y.M. Ivanova, V.I. Pavlov, V.A. Badtieva, P.A. Subbotin // Pediatrics. The journal named after G.N. Speranskij. – 2016. – Vol. 95. – № 3. – P. 65-72.

13. Gavrilova E.A. Remodeling of an athlete's heart, depending on the orientation of the training process / E.A. Gavrilova, G.M Zagorodnyi // Applied Sports Science. – 2019. – № 1(9). – P. 48-57.

14. McClean G. Electrical and structural adaptations of the paediatric athlete's heart: a systematic review with meta-analysis / G. McClean, N.R. Riding, C.L. Ardern, A. Farooq, G.E. Pieles, V. Watt, C. Adamuz, K.P. George,

D. Oxborough, M.G. Wilson // Br J Sports Med. – 2018. – Vol. 52 (4). – P. 230. DOI: 10.1136/bjsports-2016-097052.

15. Pelà G. Sex-related differences in left ventricular structure in early adolescent non-professional athletes / G. Pelà, A. Crocamo, M. Li Calzi, M. Gianfreda, M.I. Gioia, F. Visioli, P. Pattoneri, D. Corradi, M. Goldoni, A. Montanari // Eur J Prev Cardiol. – 2016. – Vol. 23(7). – P. 777-784. DOI: 10.1177/2047487315608826.

16. Castanheira J. Cardiac remodeling indicators in adolescent athletes / J. Castanheira, J. Valente-Dos-Santos, D. Costa, D. Martinho, J. Fernandes, J. Duarte, N. Sousa, V. Vaz, L. Rama, A. Figueiredo, M. Coelho-E-Silva // Rev Assoc Med Bras. – 2017. – Vol. 63(5). – P. 427-434. DOI: 10.1590/1806-9282.63.05.427.

17. D'Andrea A. Acute and Chronic Response to Exercise in Athletes: The "Supernormal Heart" / A. D'Andrea, T. Formisano, L. Riegler, R. Scarafile, R. America, F. Martone, M. di Maio, M.G. Russo, E. Bossone, M. Galderisi, R. Calabrò // Adv Exp Med Biol. – 2017. – Vol. 999. – P. 21-41. DOI: 10.1007/978-981-10-4307-9_2.

18. Graevskaya N.D. Examination of the heart of athletes using echocardiography / N.D. Graevskaya, G.A. Goncharova, G.E. Kalugina // Cardiology. – 1978. – Vol. 18(2). – P. 140-143.

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