CLINICAL FUNCTIONAL CHARACTERISTICS OF CARDIOVASCULAR AND RESPIRATORY SYSTEMS ADAPTATION IN SCHOOL CHILDREN WITH CORRECTED CONGENITAL HEART FAILURE

[1]Sh. A. Agzamova, [2]F. Sh., Yusupova, [3]M.N. Daminova
[1,2,3]Tashkent Pediatric Medical Institute, Tashkent, Uzbekistan
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Abstract. *Currently, there is no system to monitor the growing number of older children and adults with corrected CHD. In this regard, it is extremely important to actively monitor them and identify their medical problems at an early stage.*

The objective. *To determine the clinical and functional characteristics of adaptation of the cardiovascular and respiratory systems in children with CHD in the long-term postoperative period.*

Materials and methods of the research. *A prospective cohort study of 24 children was conducted (group 1 consisting of 14 children with chronic heart failure (CHF)-0 and group 2 with CHF-1, the first functional class (1FC). The study included assessment of physical development; determination of the clinical and functional state of the cardiovascular system (electrocardiography, measurement of blood pressure, pulse rate, with calculation of the Kerdo index and determination of types of blood circulation auto regulation(CAR)); assessment of the function of external respiration (peak flowmetry, Stange and Gencha tests).*

Results. *It was found that the decrease in the adaptive capabilities of the cardiovascular system was 42.8 (RR=42.8) times higher in children with CHF-1 compared to the children without CHF and was characterized by sharp decrease in the influence of sympathetic regulation on cardiac activity, as well as the predominance of the vascular type of blood circulation regulation, indicating decrease in the adaptive capabilities of the cardiovascular system. It was revealed that in children with CHD in the long-term postoperative period, there was a significant decrease in the values of the peak exhalation rate according to the results of peak flowmetry and reduction in the duration of breath retention in seconds according to Stange and Gencha functional tests.*

Keywords: *children, congenital heart defects, long-term postoperative period, adaptation, cardiovascular system, respiratory system*

Relevance. Nowadays congenital heart defects (CHD) serve to be the main cause of childhood morbidity and mortality associated with congenital developmental defects. At the same time, the survival rate of children with CHD depends on the complexity of the defect, the time of its diagnosis, and of course, the type and form of correction, as well as the presence or absence of other defects. Birth weight which is also important can affect the survival until a young age [1]. According to statistics from the National Center on Birth Defects and Developmental Disabilities, Centers for Disease Control and Prevention (USA), about 97% of children born with non–critical CHD can live up to at least a year, while only 75% of children with critical complex CHD can do the same. Approximately one in 4 children with CHD has a critical form of the defect and requires qualified medical intervention [1].

According to Downing K.F., et al. (2021), approximately 2 out of every 5 adults with CHD have a disability [2]. The researchers studied the prevalence of disability and related characteristics among people aged 19 to 38 years old with CHD from 3 US cities over the period of 2016-2019. The prevalence of various types of disability (impaired hearing, vision, cognitive abilities, mobility, self-care, reduced frequency of independent lifestyle) among adults with CHD was 5-8 times higher than in the general population [2]. Other scientists noted that from 20% to 30% of people with CHD had physical, cognitive and developmental problems [3, 4, 5]. Children with CHD are about 50% more likely to receive special education services compared with those without CHD [6, 7]. Almost 60% of children with progressing heart disease require special medical care compared to 20% of children without any [8].

Hospitalizations of children with CHD amounted to about $5.6 billion in hospital costs, which is 15.1% of the total cost of all pediatric hospitalizations in 2009 in the United States [9].

Currently, there is no system to monitor the growing number of older children and adults with corrected CHD. In this regard, it is extremely important to actively monitor them and identify their medical problems at an early stage. It is vital to know the parameters that indicate the initial state of children with CHD in accordance with physical activity levels, exercise tolerance, nutritional status and quality of life. These will be key indicators that need to be taken into account in the future in order to adapt rehabilitation plans that will reduce the effects of their condition.

The objective. To determine clinical and functional characteristics of adaptation of the cardiovascular and respiratory systems in children with CHD in the long-term postoperative period.

Materials and methods of the research. We conducted a prospective cohort study of 44 children aged 7 to 14 years old (average age 11.2±0.43 years), of which 24 children diagnosed with CHD, postoperative condition (main group) and 20 practically healthy children included in the control group the group on the basis of Tashkent Yunusabad District Medical Association within the period 2021-2023. Depending on the presence of chronic heart failure (CHF) the children of the main group were divided into: 1st group of children (n=14; 8 boys and 6 girls) without CHF (CHF-0) and 2nd one of the children with CHF-1, the first functional class (1FC) (n=10; 6 boys and 4 girls). The severity of CHF was determined based on complaints, anamnestic data and physical examination according to the ACC/ANA classification (American Society of Cardiology/American Heart Association). The functional class of CHF was diagnosed according to the NYHA classification (New York Heart Association, 1964) [10]. Inclusion criteria were as follows: children aged 7-14, diagnosed with CHD, condition after surgical correction of a defect with CHF-0 and CHF-1, 1-FC, informed parental consent. Exclusion criteria were the following: acute diseases during the study period, chronic diseases affecting the results of the study.

The analysis of the obtained data classified by gender showed that among the examined patients who were registered for CHD, boys prevailed over girls (58.3% versus 41.7% girls) without significant differences. However, the literature data indicate the opposite, namely, that girls suffer from congenital pathology of the cardiovascular system more often [11]. More than half of the children did not have CHF, which indicates the disappearance of hemodynamic disorders after cardiac surgical correction of CHD in 58.3% of the cases. In the Russian Federation, according to A.A. Baranov et al. (2016) positive dynamics after surgery can be observed in 78% of cases [12].

CHD was diagnosed in accordance with the generally accepted classification based on the clinical and instrumental manifestations of the disease. Septal defects were most often recorded, namely in 66.7% (16) of the cases, with VSD in 11 children (68.7%) and ASD in 5 children (31.3%). Open ductus arteriosus was observed in 16.7% (4) of the cases, the Fallot triad in 2 children (8.3%), pulmonary artery stenosis, and transposition of the main vessels occurred with equal frequency in 4.15% (1 child each) of the cases. The diagnosis of CHD, in most cases, was established before the age of 1 year old (13/54.2%) and surgical correction was performed in 25.0% (6) of the cases. In 11 children (45.8%) were diagnosed with CHD in the third year of life, 14 (58.3%) had surgery before the age of three, while 4 (16.7%) had surgical correction when they were over 4 years.

The research methods included collecting patient complaints and from the words of mothers, physical examination, as well as copying data from medical documentation (f-111, f-25-u) with the verification with the results of examination; examination by specialists (in order to exclude hereditary pathology), assessment of physical development (anthropometry: weight, height, body mass index according to WHO standards, [13]); determination of the clinical and functional state of the cardiovascular system (electrocardiography, measurement of blood pressure, pulse rate, with calculation of Kerdo index and definition of types of blood circulation auto regulation (CAR)); assessment of the function of external respiration, peak flowmetry, Stange and Gencha samples; ECG diagnostics in standard, enhanced precardial and thoracic leads. The data of N.A.Belokon et al. were taken as indicators of normal ECG in children in the age range of school age and the data of R.A.Kalyuzhnaya for the teenage period of childhood.

Statistical processing of the obtained results was carried out using parametric methods (Student's t–test, Prison correlation analysis) and nonparametric statistics. To assess the basic risk, we calculated the relative risk indicator (RR) [14].

The results of the study and their discussion. The analysis of the indicators of physical development of children with corrected CHD and the control group is presented in Table 1. According to the table, it can be seen that the parameters of height, weight and body mass index (BMI) of almost all children in the control group were within the range of normal values, namely between -1CO and +1CO standard deviations (CO), with the exception of 3 girls and 3 boys with the risk of low height and the risk of underweight and low height, respectively.

But among the children of the main group, the frequency of disharmonious development prevailed (19.79.2%) with a significant difference compared to the control (6.30.0%, $p<0.05$). At the same time, the indicator of very low growth was recorded in two children of the 2nd group (20.0%). Identical trend can be observed in terms of weight by age: underweight in 6 boys (25.0%) and 5 girls (20.8%).

Obviously, this indicator was registered more often among the children of the 2nd group (60.0%) than among the children in the 1st group (5.35%).

According to the parameters of the body mass index (BMI), the risk of protein-energy malnutrition/ exhaustion was established in 4 children of the 1st group (28.6%) and 4 in the 2nd (40.0%), with a slight prevalence among the girls of the 2nd group (2, 50.0%).

Protein energy malnutrition/moderate exhaustion was characteristic only for the children with CHD and it was more often registered among the children of the 2nd group (5, 55.5%), prevailingly among boys (Fig. 1).

Table 1

Prevalence of disproportional physical development among the children with CHD within postoperative period dependently on gender

Parameters	Control n=20		1st group n=14		2nd group n=10	
	F (n=8) abs/%	M (n=12) abs/%	F (n=6) abs/%	M (n=8) abs/%	F (n=4) abs/%	M (n=6) abs/%
Height: between -1CO and -2CO	2/25.0	2/16.7	3/50.0	3/37.5	1/25.0	1/16.7
between -2CO and -3CO	1/12.5	1/8.3	3/50.0	4/50.0	2/50.0	3/50.0
below -3CO	-	-	-	-	1/25.0	1/16.7
Weight: between -1CO and -2CO	1/12.5	2/16.7	4/66.7	4/50.0	1/25.0	2/33.3
between -2CO and -3CO	-	-	2/33.3	3/37.5	3/75.0	3/50.0
BMI: between -1CO and -2CO	-	-	2/33.3	2/25.0	2/50.0	2/33.3
between -2CO and -3CO	-	-	1/16.7	2/25.0	2/50.0	3/50.0

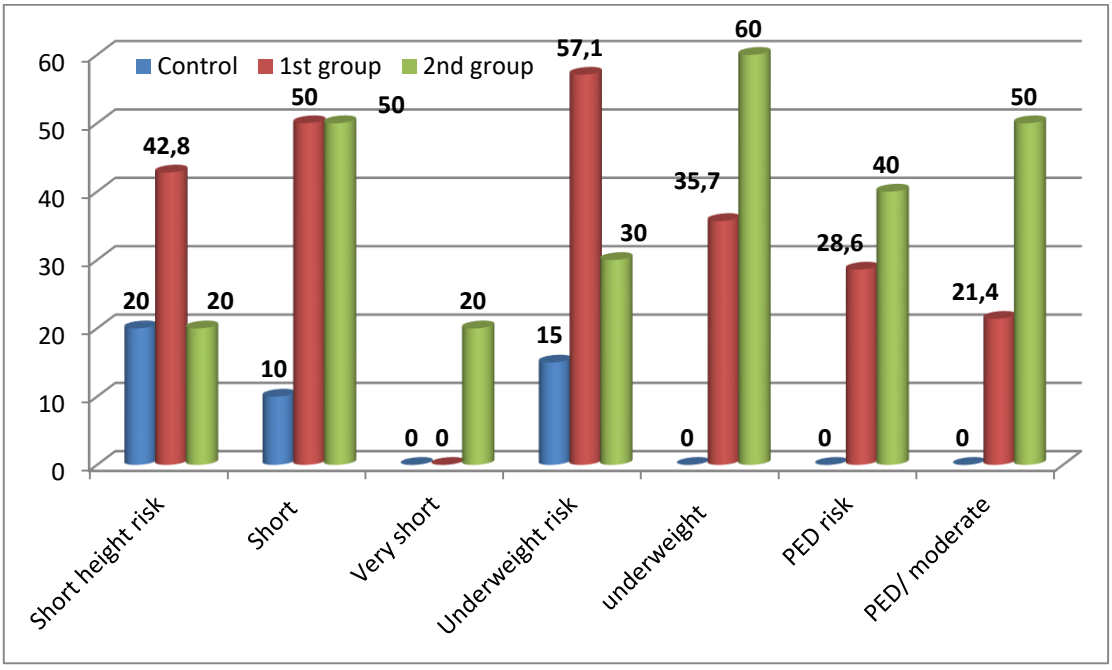

Figure 1. Prevalence of disproportional physical development among the children with CHD within postoperative period

Thus, disproportional development in 79.2% of the cases was inherent in children with corrected CHD in the postoperative period with a significant difference in relation to practically healthy children (30.0%, $p<0.05$). Moreover, retardation in physical development was more often registered in children with CHF-1 stage, 1-FC (80.0%).

The comorbidity of children with corrected CHD was quite high. These children were more likely to suffer from acute respiratory viral infections, acute bronchitis, pneumonia ($p<0.05$), exacerbation of chronic tonsillitis ($p<0.05$) with concomitant vegetative dystonia. Diseases of the gastrointestinal tract (chronic gastritis, gastroduodenitis, colitis, $p<0.05$), musculoskeletal system (impaired posture, flat feet) were also detected (Table 2).

Table 2

Characteristics of comorbid status among the children with CHD (%)

Disease or pathological state	Control	Main groups
Often sick	20	58.3*
GIT pathology	15	37.5*
ENT pathology	20	41.7*
Poor posture, flat feet	15	29.2
Vegetative dystonia	30.0	58.3

NB: * - reliability of the data compared to the control ($p<0.05$).

Children of the main group often complained of headaches (14, 58.3%, compared to the control of 25%, $p<0.05$) with a predominance of the children of the 2nd group (7, 70.0%, $p<0.01$), increased fatigue (13, 54.2%, versus the control of 25%, $p<0.05$), impaired night sleep (10, 41.7%, versus 30.0% in the control).

CHF of the I stage in children of the 2nd group was characterized by the fact that children felt comfortable at rest, and there was a slight restriction in physical activity. But regular physical activity caused shortness of breathing, fatigue or palpitations, whereas in children of the 1st group these conditions were absent, and there were no restrictions in physical activity.

The study of the heart condition in the three compared groups revealed percussion and auscultative disorders in the functioning of the heart in children of the main groups. Percussion revealed increases in the size of relative dullness to the left (9, 37.5%), and to the left and right (5, 12.0%). During auscultation, systolic noise was heard at the apex and at the Botkin point (15, 62.5%), there was accent of the second tone above aorta (8, 33.3%).

The electrocardiogram revealed sinus arrhythmias in the form of tachy- and brady-arrhythmias, low-voltage ventricular complex, violations of ventricular reopolarization processes in the children of the 2nd group (70.0%). Paired ventricular extrasystoles were significantly more common in children of the 2nd group (40.0%, $p<0.01$), whereas in group 1 they accounted for 7.1% of the cases. There were signs of hypertrophy of the left ventricle (9, 37.5%), both ventricles (5, 12.0%), and hypertrophy of the right atrium (7, 29.2%).

The average values of Kerdo index (KI) and types of blood circulation auto regulation (CAR) in children with CHD in a comparative aspect are shown in Figure 2. According to the presented data, it was found that the KI parameters in children of the control group (+8.4%) and the 1st main group (+7.3%) were in the range of normative values. These KI indicators indicate a uniform regulation of the activity of the heart by the sympathetic and parasympathetic parts of autonomic nervous system. But in children of the 2nd group the average KI value was +2.3%, which is 3.6 and 3.2 times lower compared to the control and parameters of children of the 1st group, respectively. A sharp decrease in these values in the children of the 2nd group indicates the debilitating nature of the sympatho-adrenal system and has a prognostic value in exacerbating chronic heart failure [18, 19].

According to the types of blood circulation auto regulation in children of the control and the 1st groups, the frequency of cardiovascular type was statistically significantly higher (60.0%, 50.0%, respectively) in relation to the children of the 2nd group (20.0%, $p<0.01$ and $p<0.05$, respectively). The average heart rate was typical for children of the control (35.0%) and 1st groups (28.6%), the lowest was only in the 2nd group (10.0%, $p<0.05$, compared to the control). Vascular type of auto regulation was more common among the children of the 2nd (70.0%, $p<0.001$) and 1st (21.4%, $p<0.05$) groups, with a significant difference in relation to the control (5.0%).

The vascular type of CAR is characterized by depressed functioning of the cardiovascular system and a decrease in its adaptive capabilities and is considered a more unfavorable type of CAR [20, 21].

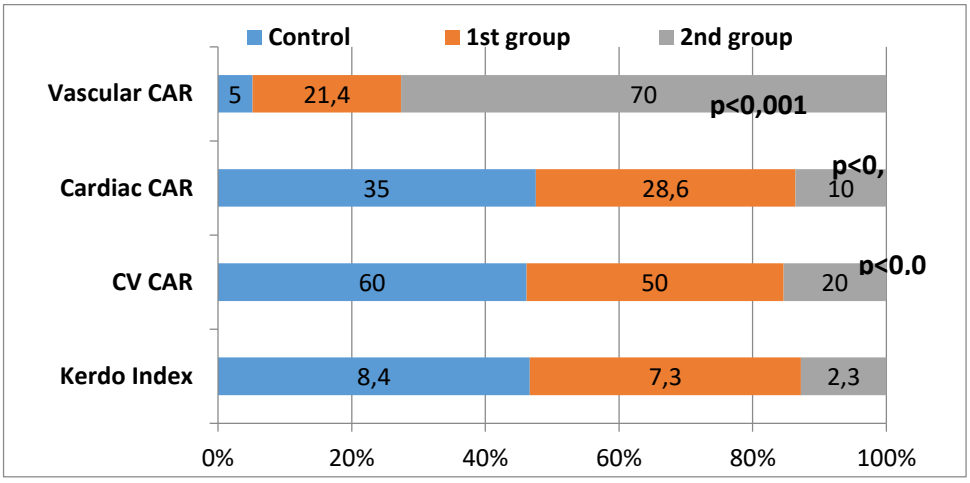

Figure 2. Kerdo Index characteristics and blood circulation auto regulation types in the studied groups of children

Thus, the decrease in the adaptive capabilities of the cardiovascular system is 42.8 (RR=42.8) times higher in the children of the 2nd group compared to the children of the 1st group and is characterized by a sharp decrease in the influence of sympathetic regulation on cardiac activity, as well as the predominance of the vascular type of blood circulation auto regulation, indicating a decrease in the adaptive capabilities of the cardiovascular system.

A comparative analysis of the peak flowmetry of children with corrected CHD, depending on age, is presented in tables 3 and 4. Decrease in the average peak flowmetry of children of the main groups was found both in the age range of 7-9 and in 10-14 years old with a statistically significant difference to the control.

Table 3

Comparative analysis of peak flowmetry in children aged 7-9 years old in the studied groups

Peal flowmetry	**Control (n=9)**	**1st group (n=5)**	**2nd group (n=5)**
Mean values (L/min)	245.5±6.1	235.4±3.6	195.7±5.4**
% of normal value	99.8±2.2	81.2±3.5	79.8±3.1**

NB: * - reliability of the data compared to the control ($p<0.05$)

Similar changes were noted in the analysis of the results of pulmonary tests by Stange and Gencha. The results of determining the time of maximum breath retention after 3 deep breaths (Stange test) and exhalation (Gencha test) are presented in Table 5.

Table 4

Comparative analysis of peak flowmetry in children aged 10-14 years old in the studied groups

Peak flowmetry	Control (n=11)	1st group (n=9)	2nd group (n=5)
Mean values (L/min)	290.5±8.0	271.3±4.6	244.6±4.7**
% of the normal value	98.7±2.3	81.3±2.5	75.6±3.3

NB: * - reliability of the data compared to the control (p<0.05)

Table 5

Results of breath retention test in the studied groups of children dependent on the age

Seconds in tests	7-9 years old		10-14years old	
	1st group (n=5)	2nd group (n=5)	1st group (n=9)	2nd group (n=5)
Stange	25.1±7.6	21.1±7.1	34.9±9.0	31.1±8.7
	27.2±8.0	22.7±7.3	35.8±9.2	32.2±9.1
Normal	36±5	36±5	50±7	50±7
Gencha	13.1±5.5	12.9±5.5	16.5±6.2	16.4±6.2
	11.3±7.5	11.6±5.2	14.7±5.8	14.0±5.7
Normal	14±2.1	14±2.1	22±3.0	22±3.0

According to the presented data, it can be seen that in practically healthy children, the parameters of peak flowmetry increase with age, indicating physiological morphofunctional differentiation of the bronchopulmonary system. At the same time, starting from the age of 6-7, the volume of inhalation and exhalation increases due to a decrease in bronchial resistance, and from the age of 10-11, the lung tissue grows intensively, increasing the functionality of the external respiration function. But in children with CHD in the long-term period after surgical correction, we note a different picture, namely, significant decrease in the values of the peak exhalation rate and a reduction in the duration of breath retention in seconds. Increased pressure in the pulmonary artery as a result of late surgical correction of the defect and the development of CHF leads to slowdown in the maturation of lung tissue and a decrease in the reserve capacity of the respiratory system. It is known that the value of peak flowmetry depends not only on age, but also on the height and sex of the child, so we can note high percentage of physical development retardation in children, especially in group 2 and among girls. At the same time, a direct correlation was established between the parameters of peak flowmetry and the growth of the children of the 2nd group with the absence of this relationship in the children of the control and 1st groups.

Conclusions. Disproportional development in 79.2% of the cases was inherent in children with corrected CHD in the postoperative period with a significant difference in comparison to practically healthy children (30.0%, p<0.05). Moreover, retardation in physical development was more often registered in children with chronic heart failure of the 1st stage and I functional class (80.0%).

Electrocardiography revealed sinus arrhythmias, low-voltage ventricular complex, violations of ventricular repolarization processes (70.0%), and paired ventricular extra systoles were significantly more common in children with CHF-1 (40.0%, p<0.01), whereas in group 1 they amounted to only 7.1% of the cases. There were signs of hypertrophy of the left ventricle (9.37.5%), both ventricles (5.12.0%), and hypertrophy of the right atrium (7.29.2%).

It was found that the decrease in the adaptive capabilities of the cardiovascular system was 42.8 (RR=42.8) times higher in children of the 2nd group compared to the children of the 1st group and was characterized by a sharp decrease in the influence of sympathetic regulation on cardiac activity, as well as the predominance of the vascular type of auto regulation of blood circulation, indicating decrease in the adaptive capabilities of the cardiovascular system.

It was revealed that in children with CHD in the long-term postoperative period, there was significant decrease in the values of the peak exhalation rate according to the results of peak flowmetry and reduction in the duration of breath retention in seconds according to Stange and Gencha functional tests.

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