Article

Gender Features of Autonomic Regulation of Cardic Activity in Young Athletes

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Abstract: Background. The success of sports activities depends on the level of the athlete's functional state. The study of heart rate variability will help determine the adaptive capabilities and state of cardiac reserves in athletes as they currently are, as well as predict sports results. The purpose of this study is to study gender characteristics of the autonomic regulation of cardiac activity in children involved in sports.
Materials and methods. The study involved 22 children aged 12-18 years. All study participants were divided into two groups: group 1 (n=10) – boys and group 2 (n=12) – girls. Heart rate, systolic and diastolic blood pressure, weight and height were measured non-invasively. Based on the data obtained, adaptation potential, body mass index, and Kerdo index were calculated. When assessing heart rate variability, the autonomic balance index (ABI), autonomic rhythm index (ARI) and tension index (TI) of regulatory systems were calculated. Statistical analysis was performed using t-test, U-test and Chi-square test ($\chi 2$).
Results. In both groups, satisfactory adaptation of the cardiovascular system (CVS) to physical activity was noted (BP <2.6), but the value of this indicator was 7.25% higher in boys ($p < 0.001$), which indirectly indicates that The functional reserve of the cardiovascular system in adaptation to physical activity is better in girls. When calculating the Kerdo index and studying heart rate variability (HRV), it was found that 50% of boys have sympathetic tone and 10% have parasympathetic tone. In the group of girls, an increase in the tone of the sympathetic division of the ANS occurs significantly more often by 8.3%. The RRNN value in the boys group is 15% higher than in the girls group ($p < 0.001$). The NN50 and pNN50 values were also higher among boys by 44.87% and 41.17%, respectively ($p < 0.05$). SDNN and RMSSD in the girls group are less by 25.5% ($p < 0.01$) and 34.5% ($p < 0.05$), respectively. The average heart rate is 11.6% higher among girls ($p < 0.01$). IVR, VPR and IN were greater in the girls group by 32.8%, 32.9% and 50.8%, respectively ($p < 0.01$).
Conclusions. Satisfactory adaptation of the body to physical activity was evident in both gender groups. Linear rhythmogram and column histogram data show that HRV is higher in the boys group, and the stress index is higher in the girls group.

Keywords: heart rate variability and adaptation, child athletes, Kerdo index, adaptive potential, cardiovascular system.

1. Introduction

Current tasks of sports and the high level of sports achievements indicate the need to study the functional capabilities of the cardiovascular system (CVS), which is a key link in the adaptation of the human body to increased physical activity (PE) [1]. The success of sports activities is directly related to the level of the functional state of the body [2, 3]. The main signs characterizing a high level of the functional state of the cardiovascular system include bradycardia, hypotension and physiological hypertrophy of the myocardium. Rational exercise leads to an improvement in the morphological and functional characteristics of the heart and blood vessels. The heart of an athletic person combines economical activity at rest and the achievement of maximum performance during physical activity [1].

The functional activity of the body is regulated through the joint work of the central nervous system (CNS), immune and endocrine systems. The autonomic nervous system (ANS), which provides adaptive regulation, determines the consistency and, ultimately, the effectiveness of the regulatory systems of the athlete's body [4, 5]. The outcome of exposure to stress factors on the body depends on the level of the functional state of the ANS. Economization and mobilization of functions at rest and during exercise determine adaptive changes in regulatory processes, thereby ensuring variability and variability of regulation under the expected background conditions of activity [6, 7]. The model of heart rate regulation is based on the already studied mechanisms of regulation of the sinoatrial node of the heart. There are autonomous and central regulatory loops. The first of them, autonomous, is formed from the cells of the sinoatrial node themselves with the participation of the parasympathetic division of the ANS. Another circuit, the central one, includes three levels; it provides intrasystem control, hormonal-vegetative homeostasis and interaction of the body as a whole with the external environment [8].

The ANS of adolescent children undergoes a certain transformation due to active hormonal changes. The regulatory functions of the ANS develop unevenly due to the fact that during puberty, significant changes are observed in the ratio both between the severity of sympathetic and parasympathetic, and in the ratio between the segmental and suprasegmental levels of regulation of the activity of the cardiovascular system [9]. During puberty, problems of autonomic nervous regulation arise, such as a decrease in HRV as a consequence of dysregulation of metabolic control [10].

Thus, the autonomic regulation of cardiac activity has gender differences. Assessing the functioning of all regulatory circuits will make it possible to fully determine the adaptive capabilities and state of the athlete's body reserves at the present time and predict the sports result.

2. Patients and Methods

The study was conducted on the basis of the SSOR for cycling in the city of Saransk from September 19, 2022 to October 22, 2022. The study involved 22 children aged 12 to 18 years. All study participants were divided into 2 groups: group 1 (n=10) – boys, group 2 (n=12) – girls. The average age of the participants was 14.9±0.2 years in group 1 and 15.25±0.3 in group 2.

We non-invasively measured heart rate (HR), systolic and diastolic blood pressure (SBP and DBP), body weight, and height. Based on the data obtained, we calculated the adaptation potential (AP) of the CVS using the formula of R. M. Baevsky [11]. Body mass index (BMI) was assessed using SDS tables [12] and centile scales (WHO, 2007). To assess the impact of VNS, the Kerdo index (KI) was used.

Using the BiTronics Lab, a training laboratory for neurotechnology, HRV was assessed using a linear rhythmogram and a column histogram. Short five-minute recordings were used in accordance with the International Standard [13]. The vegetative balance index (ABI), the vegetative rhythm index (VRI) and the tension index of regulatory systems (IN) were calculated.

The distribution of the obtained data corresponds to the law of normal distribution. For indicators for which the differences were not statistically significant, the U test was used. For parametric analysis, t-test and Chi-square test (χ2) were calculated.

Statistical analysis was performed using the U test and correlation analysis (SPSS Statistics 13) was used.

3. Results and discussion

As part of the study, AP, BMI, KI were calculated, HRV was analyzed and gender differences were identified.

On average, the AP value in group 1 was 1.33±0.016, and in group 2 – 1.24±0.015. In a comparative aspect, the value of this indicator is higher in group 1 by 7.25% ($p<0.001$).

It was found that on average SBP fluctuated within the normal range and amounted to 121.1±0.66 mm Hg in group 1, which is 5.03% more than in group 2 ($p<0.001$). DBP was also normal in both groups and amounted to 78.8±0.37 mm Hg in group 1 and 72±0.57 mm Hg in the 2nd group. In comparative terms, this indicator is higher in group 1 by 9.4% ($p<0.001$). As for KI, its value averaged 30.9±0.99% in group 2, which is 276.1% more than in group 1 (see Table 1). In group 2, increased tone of the sympathetic division of the ANS occurs more often by 8.3% ($p<0.001$).

BMI in group 1 averaged 20.58±0.37 kg/m2, and in group 2 – 20.86±0.22. This indicator does not depend on gender ($p>0.05$), however, it was found that in group 1, deviations in BMI in the direction of increasing and decreasing were observed 3.3% more often than in girls (see Table 1).

Table 1. Distribution of the studied indicators in children of different sexes

Index	Interpretation of the indicator	1st group (boys, n=10)	2nd group (girls, n=12)	χ^2,p
Height, m		1,7±0,01	1,63±0,003	–
Weight, kg		62,14±1,73	56,09±0,65	–

Body mass index, kg/m²	Average BMI, kg/m²	20,58±0,37	20,86±0,22	0,65 (p>0,05)
	Body weight deficiency (SDS<-2.0),%	20	16,7	0,94 (p>0,05)
	Normal body weight (SDS±1.0)	60	66,6	
	Excess body weight (+1.0<SDS<+2.0)	20	16,7	
Kerdo index, %	KI medium	11,19±1,91	30,9±0,99	9,16 (p<0,001)
	Parasympathicotonia	10	0	10,6 (p<0,01)
	Normotonia	40	41,7	
	Sympathicotonia	50	58,3	
Adaptive potential		1,33±0,016	1,24±0,015	4,1 (p<0,001)

The indicators used to analyze HRV are presented in Table 2. During the study, we found that RRNN (arithmetic mean of the duration of NN intervals in the analysis epoch) averaged 828±15 ms. in group 1, which is 13% more than in group 2 (p<0.001).

The total number of NN intervals (N) was 183.2±7.25 and 214.5±7.82 among adolescents of the 1st and 2nd groups, respectively. In comparative terms, this indicator is higher by 17.08% in group 1. The number of pairs of studied NN intervals that differ by more than 50 ms. (NN50) in group 1 averaged 48.1±4.4, which is 44.87% more than in group 2 (p<0.05). The proportion of NN50 from the total number of NN intervals (pNN50) in group 1 was 0.24±0.02, and in group 2 it was 0.17±0.018. In comparative terms, this indicator is higher in group 1 by 41.17% (p<0.05). The number of pairs of studied NN intervals that differ by more than 20 ms. (NN20) was also higher in group 1, where this indicator was 82.7±5.64, which is 25.1% more than in group 2 (p<0.05). The standard deviation of mean NN intervals (SDNN) was 149 ± 14 ms. in group 2, which is 25.5% less than in group 1 (p<0.01). The root mean square of successive differences (RMSSD) was 269 ± 20 ms. in group 1 and 200±22 ms. in the 2nd group. In comparative terms, this indicator is higher in group 1 by 34.5% (p<0.05). Heart rate averaged 92.25±1.88 and 103±2.15 for groups 1 and 2, respectively. In comparative terms, the value of this indicator is higher among adolescents of the 2nd group by 11.6% (p<0.01).

In group 2, the average IVR value was 85±4, which is 32.8% more than in group 1 (p<0.01). VPR was also greater in group 2 by 32.9% (p<0.001). The stress index (SI) value was 51.7±0.03.9 and 78.0±5.7 for groups 1 and 2, respectively. Comparing the results obtained, we can conclude that the IN is greater in group 2 by 50.8% (p<0.01).

Table 2. Heart rate variability in children of different sexes

The indicator being studied	1st group (boys, n=10)	2nd group (girls, n=12)	p
RRNN, ms.	828±15	720±10	4,99 (p<0,001)
SDNN, ms.	200±10	149±14	2,96 (p<0,01)
N	183,2±7,25	214,5±7,82	2,94 (p<0,05)
CV, %	30,37±2,09	23,21±2,08	2,43 (p<0,05)
RMSSD, ms.	269±20	200±22	2,32 (p<0,05)

Mo, s.	0,675±0,015	0,597±0,01	4,33 (p<0,001)
AMo, %	0,43±0,019	0,48±0,014	2,12 (p>0,05)
NN50	48,1±4,4	33,2±3,2	2,74 (p<0,05)
pNN50, %	24±2	17±1,8	2,6 (p<0,05)
NN20	82,7±5,64	66,1±5,21	2,16 (p<0,05)
pNN20, %	42±2	36±2,6	1,83 (p>0,05)
ЧСС	92,25±1,88	103±2,15	3,76 (p<0,01)
ИВР	64±3,7	85±4	3,85 (p<0,01)
ВПР	2,28±0,082	3,03±0,147	4,46 (p<0,001)
ИН	51,7±3,9	78±5,7	3,81 (p<0,01)

The results obtained showed that both groups had satisfactory adaptation of the cardiovascular system to physical activity (AP <2.6). Since in 1 the AP value is greater than in 2, this may indirectly indicate a better adaptation of the CVS of girls to physical activity.

An KI value in the range from -10 to +10% is considered normal; positive values of this indicator, beyond this range, indicate the predominance of the influences of the sympathetic nervous system, negative values indicate the predominance of the tone of the parasympathetic nervous system. When analyzing the KI values in both groups, it was found that 50% of adolescents in group 1 are sympathicotonic and 10% are parasympathicotonic. In group 2, we revealed a predominance of sympathicotonics.

Considering the fact that parasympathetic influences reduce heart rate and increase RRNN, we can conclude that children of group 1 have a higher tone of the parasympathetic part of the nervous system than children of group 2. A study by R. Abrarov et al [14] showed in a similar group of children the predominance of the sympathetic link in the autonomic regulation of heart rhythm. However, the authors included healthy children in their study, and we included child athletes, so the differences obtained can be explained by the fact that athletes have higher HRV.

The pNN50 indicator is used to assess the predominance of the parasympathetic component of autonomic regulation (VR) over the sympathetic one. Since the value of this indicator is higher in group 1, we conclude that the parasympathetic type of VR is statistically more common in boys.

The SDNN indicator reflects the total effect of the autonomic regulation of the heart and allows us to conclude that in group 1, the predominance of the autonomic regulation of the heart is observed statistically more often. In a study by M. S. Ishbulatova, SDNN increases in different groups of children aged 9-11 years and on average reaches 93.37 ± 10.08 ms. for boys and 81.35±9.2 ms. for girls [15]. Comparing the results of the author's study with ours, we can conclude that in boys the autonomic regulation of heart rate actually predominates, but in our case the value of the studied indicator turned out to be greater, which probably indicates greater HRV in child athletes.

RMSSD is an indicator that allows you to assess the activity of the parasympathetic part of the ANS. This gives us the right to conclude that in children of group 1, the activity of the parasympathetic component of the ANS is statistically more likely to predominate. The obtained result is comparable to the results of studies by other authors. In the same study by M. S. Ishbulatova, RMSSD among boys 9-11 years old was greater compared to girls of the same age and averaged 111.27 ± 14.03 ms. [15].

Taking into account the results obtained, namely the values of RRNN, pNN50, SDNN, RMSSD in both groups, we conclude that adolescents of group 1 have higher HRV than adolescents of group 2.

IVR shows the relationship between the activity of the sympathetic and parasympathetic divisions of the ANS. VPR reflects the balance of regulation of the cardiovascular system by the sympathetic and parasympathetic divisions of the ANS. It is known that an increase in these indicators indicates the predominance of the sympathetic link in the regulation of the ANS. The stress index (SI) indicates the degree of influence of the nervous system on the functioning of the heart.

The calculated indices were lower in group 1, on the basis of which we established that parasympathetic influences predominate in this group and this confirms our conclusion that HRV is greater in group 1.

4. Conclusions

1. In both groups, there is satisfactory adaptation of the cardiovascular system to physical activity, but in girls the AP value is 7.25% less than in boys (p<0.001), which may indirectly indicate better adaptive capabilities of the girls' body.

2. The predominance of the tone of the parasympathetic division of the ANS is typical for the group of boys, where 10% of children are parasympathetic; among girls, an increase in the tone of the sympathetic division of the ANS is more common by 8.3% (p<0.001).

3. Taking into account the values of RRNN, pNN50, SDNN, RMSSD, heart rate, as well as the results of the stress index, autonomic rhythm index and autonomic balance index, heart rate variability is higher in the group of boys.

Application of artificial intelligence: The article is written without the use of artificial intelligence technologies.

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