ORIGINAL ARTICLE

ADAPTIVE CAPABILITIES OF MIDDLE SCHOOL-AGED GIRLS DEPENDING ON THE RATIO OF ADIPOSE AND MUSCLE TISSUE

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ABSTRACT

The aim: This study aimed to determine the dependence of adaptive capacities of middle school-aged girls with excessive body weight and increased volume of adipose tissue on the ratio of adipose and muscle tissue volume.

Materials and methods: 52 female subjects aged 10-12 years were examined and divided into 3 groups according to their BMI. Cardiorhythmogram was recorded in all subjects using the "CardioLab" hardware-software complex. The indices of heart rhythm variability (HRV) were determined at rest and after an active orthostatic test based on the recorded cardiothythmogram. Body weight and total fat tissue amount were determined using the Tanita BC-601 device.

Results: The analysis of HRV indices revealed features of autonomic rhythm regulation depending on morphological body features of the middle school-aged girls, namely, on the amount of fat and muscle tissue. Obese subjects had higher values of VLF %, LF % and LF/HF indices, which indicate a higher sympathetic influence on cardiovascular system activity and less significant parasympathetic division of the autonomic nervous system (ANS), as well as the PARS index. This trend of HRV indices points to an unsatisfactory level of adaptation, tension of the regulatory systems and the possibility of their failure. In contrast, subjects with normal and excessive body weight had higher values of HF ms^2, HF % and TR ms^2, and lower values of VLF %, LF/HF and PARS, which points to the dominance of the parasympathetic part of the ANS, lower level of tension in their regulatory systems, a satisfactory level of adaptation, satisfactory functional reserves of the cardiovascular system and high capabilities of the body.

Conclusions: Obese girls exhibited disturbances in the ANS functional state towards sympathicotony and increased functional activity of suprasegmental ANS divisions, which can be interpreted as an autonomic dysfunction.

KEY WORDS: heart rate variability, autonomic nervous system, children, excess body weight, obesity, adaptive capacity of the body

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INTRODUCTION

In recent years an increasing number of people are diagnosed with excessive body weight and obesity both among the adult population and among children and adolescents [1,2]. However, despite the rate of increase in prevalence, these conditions are probably still insufficiently understood as health care problems. Nevertheless, the published literature has thoroughly elucidated the clinical and social significance of obesity as a trigger factor and an aggravating cause of a large number of diseases that lead to reduced life quality and expectancy. [1,3]. The cause for concern in children with an increased amount of adipose tissue is the triggering of mechanisms that form a springboard for early manifestation of cardiovascular, endocrine, reproductive, neoplastic, cerebrovascular, musculoskeletal, and other diseases [1,3]. Childhood obesity also leads to short- and long-term adverse effects on physical and psychosocial health, which are important for general well-being [4,5].

Childhood obesity is also characterized by disorders of the autonomic nervous system (ANS) [3], which is crucial in ensuring the harmony of physiological processes and adaptation to various environmental factors. The occurrence of disorders of the ANS is in turn important in the pathogenesis of functional abnormalities of various organs and systems that can cause the development of chronic diseases and irreversible changes in adulthood. Therefore, investigating the level of functional reliability of the organism in children with an excessive amount of fat tissue is interesting, on the one hand, because of the insufficient maturity of autonomic support systems and mechanisms of their regulation, and on the other hand, because of the chronic inflammation of adipose tissue, which is accompanied by the production of proinflammatory agents, the synthesis of which grows proportionally to the level of obesity and distribution of adipose tissue in the body [6].

Currently, the standards for assessment of the functional state are the physiological indicators reflecting the mechanisms of cardiac activity regulation. Therefore, among many existing tests, the method of heart rhythm variability (HRV) measurement and the indicator of activity of regulatory systems (PARS) suggested by R. M. Bayevsky are the most widely used, because they allow to establish typological features of autonomic regulation of heart rhythm, demonstrate the level of functional and adaptive capacities of the organism, and allow to predict and to control dynamic processes of prophylactic measures and treatment procedures [7-9].

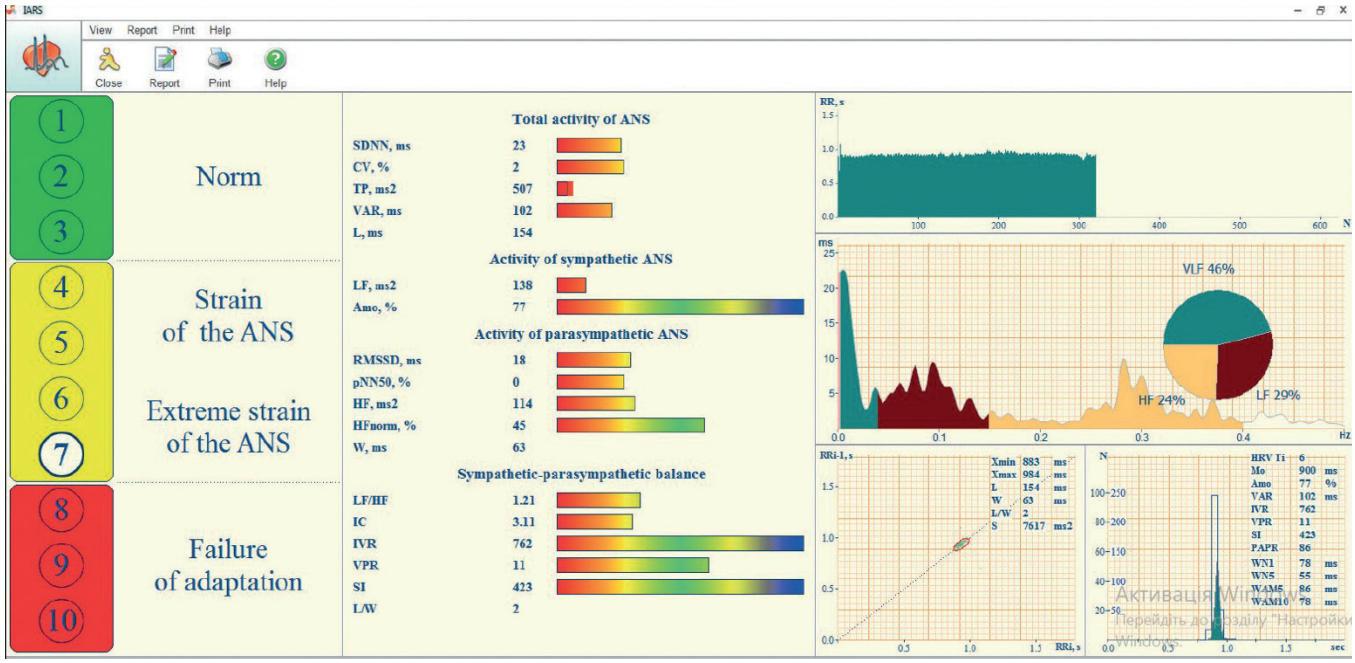

Fig. 1. Evaluation of PARS using the CardioLab device

THE AIM

The aim of this study was to determine the dependence of adaptive capacities of middle school-aged girls with excessive body weight and increased volume of adipose tissue on the ratio of adipose and muscle tissue volume.

MATERIALS AND METHODS

The study involved 52 girls aged 10-12 years without pathological changes according to the clinical examination and the principles of biomedical ethics. They were divided into 3 groups based on the body mass index (BMI). Normally, children's BMI is lower than that of adults, and its normal value is in the range from 15 to 18.5 kg/m^2, depending on the age. To characterize BMI deviations from normal values, the majority of clinicians use a 5-point scale (Table I) [10]. At the same time, the International Obesity Task Force (IOTF) recommends that children from 2 to 18 years old be considered overweight if their BMI is between 25 kg/m^2 and 30 kg/m^2, and considered obese if their BMI is >30 kg/m^2 [10,11].

In addition, current recommendations define obesity in children and adolescents if the body weight exceeds the reference values for the given age by 20% or more, and the amount of total body fat exceeds 25% for boys and 30% for girls [12]. The percentage amount of total fat (TF, %) in the bodies of examined subjects was determined using the Tanita BC-601 (Japan) scale/analyzer that functions by measuring the electrical impedance of tissues when a low-intensity constant electrical current is passed through them.

According to these considerations, Group 1 included children with BMI of 5 points, Group 2 included children with BMI of +4 and +3 points, and Group 3 included children with BMI of +2 points.

The functional state of the ANS was assessed by intervalocardiography using the hardware-software complex "CardioLab" (HAL "Medica", Ukraine), which allows obtaining spectral indices of heart rhythm variability (HRV) and characterizing the functional activity of different branches of the ANS. Specifically, the tone of the sympathetic, parasympathetic, and suprasegmental branches of the ANS was assessed by the power of the low-frequency (LF, ms^2), high-frequency (HF, ms^2), and very low-frequency (VLF, ms^2) spectral ranges respectively. The balance of the sympathetic and parasympathetic ANS branches was evaluated by the ratio of low- and high-frequency components of HRV: LF/H.

The adaptive capabilities of the subjects were assessed by the PARS value, which allows to quantitatively evaluate the functional state of the body in points, as well as by the response to the orthostatic test. The analysis of PARS values allows to diagnose the following functional health conditions: the green zone (1 to 3 points) – the normal state, satisfactory adaptation, and high functional capacities; the yellow zone (4 to 7 points) – the state of tension of the regulatory systems, decrease of the functional reserves, i.e. the premorbid state; the red zone (8 to 10 points) - the state of deterioration of the regulatory systems, failure of the adaptation processes – asenization.

Clinical assessment of the results of the orthostatic testing was done using the coefficient of response to orthostatic testing (Cr), which shows the degree of rhythm increase in percentage points during the transition process. The possible outcomes of the orthostatic test and the associated Cr values are as follows: normal, Cr below 30%; decreased, Cr below 30%; and paradoxical with rapid stabilization of rhythm; Cr above 30%.

The results were analyzed using Jamovi 0.8-1.0 software (Affero General Public License 3). The method of descriptive statistics with the estimation of arithmetic

Table I. Criteria for assessing the deviation of BMI from the ideal value according to the 5-point system.

Body weight assessment in girls							
Score Age	-2	-3	-4	5	+ 4	+ 3	+ 2
10	14.3	15.0	15.9	17.1	18.0	21.8	24.2
11	14.6	15.3	16.2	17.8	19.0	23.0	25.7
12	15.0	15.6	16.7	18.3	19.8	23.7	26.8

+4 - mild increase in body weight
+ 3 - moderate increase in body weight
+ 2 - pronounced increase in body weight
4 – mild decrease in body weight
3 - moderate decrease in body weight
2 - pronounced decrease in body weight
5 - exact correspondence of body weight to age

Table II. Mean values of HRV indicators in middle school-aged children with different BMI values (M±m)

HRV indicators	Group 1 (n=22) (BMI 5 points)	Group 2 (n=18) (BMI +4 and +3 points)	Group 3 (n=12) (BMI +2 points)
TP, ms2	3448±91	2657±163 **	1822±212 *
HF, ms2	751±81	515±148 *	181±97 **
LF, ms2	1593±10	948±125 **	713±135 **
VLF, ms2	1157±1	1024±159	957±145*
LF/HF	2,1±0,22	1,84±0,23	3,9± 0.26 **
HF, %	18,6±2.4	15,8±3,6	8,4±2.7 **
LF, %	46,0±2.7*	43,2±4. 7	38.2±2.5 *
VLF, %	35,4±3.1*	41,0±2.7*	53,4±3.9 **
PARS, units	2,164±1,617	2,579±1,625	5,478±1,581 **
Cr, %	26,5±3,9*	47,2±4,6*	66,0±5,8*

Note: Differences were statistically significant at * p≤0.05; ** p≤0.01

mean (M) and the error of the arithmetic mean (m) was used. The Mann-Whitney U-criterion was used to make a cross-group comparison of the quantitative indicators. The results were considered significant at $p<0.05$.

RESULTS

According to the BMI, the 1st group included 22 (42%) children, the 2nd group included 18 (35%) children, and the 3rd group included 12 (23%) children. The average BMI of girls in the 1st, 2nd, and 3rd group was 17.7±0.4 kg/m^2, 20.9±0.6 kg/m^2, and 25.6±0.9 kg/m^2 respectively. The percentage of total fat was 17.2±0.8%, 20.6±0.7%, and 25.3±1.2% in the 1st, 2nd, and 3rd group respectively. There was a statistically significant difference in the average values of BMI and TF% between groups 1 and 2, 1 and 3, and 2 and 3.

To evaluate the mechanisms of regulation of physiological functions of the body, the features of autonomic regulation, the relationship between sympathetic and parasympathetic branches of the ANS, and the tension of the regulatory systems and functional reserves, the analysis of HRV indices in girls with different morphological status was used. These indices are summarized in Table II.

The analysis of HRV indicators in groups of children with different BMI revealed that girls with normal and excessive body weight had similar indicators, while girls with obesity had significantly different indicators compared to the other two groups.

The TP indicator, which reflects the total level of activity of the regulatory systems, in children with normal body weight was 3448±113 ms^2, in overweight children - 2657±163 ms^2, and in children with obesity - 1822±212 ms^2. The power indicator in high-frequency range (HF) in group 1 was 751±78 ms^2, in group 2 - 515±148 ms^2, and in group 3 - 181±97 ms^2. The power in the low-frequency range (LF) in children with normal body weight was 1593±100 ms^2, in overweight children - 948±125 ms^2, and in children with obesity - 713±135 ms^2. The power in the range of very low frequencies (VLF) in the 1st group was 1157±114 ms^2, in the 2nd group - 1024±159 ms^2, and in the 3rd group - 957±154 ms^2. Low- to high- frequency ratio (LF/HF) was 2,1±0,22 in children with normal body weight, 1,84±0,23 in children with excessive body weight, and 3,9±0,26 in obese children. The value of the complex index of activity of the regulatory systems (PARS) was equal to 2,164±1,617 units in children in the 1st group, 2,579 ± 1,625 units in children in the 2nd group, and 5,478 ± 1,581 units in children in the 3rd group.

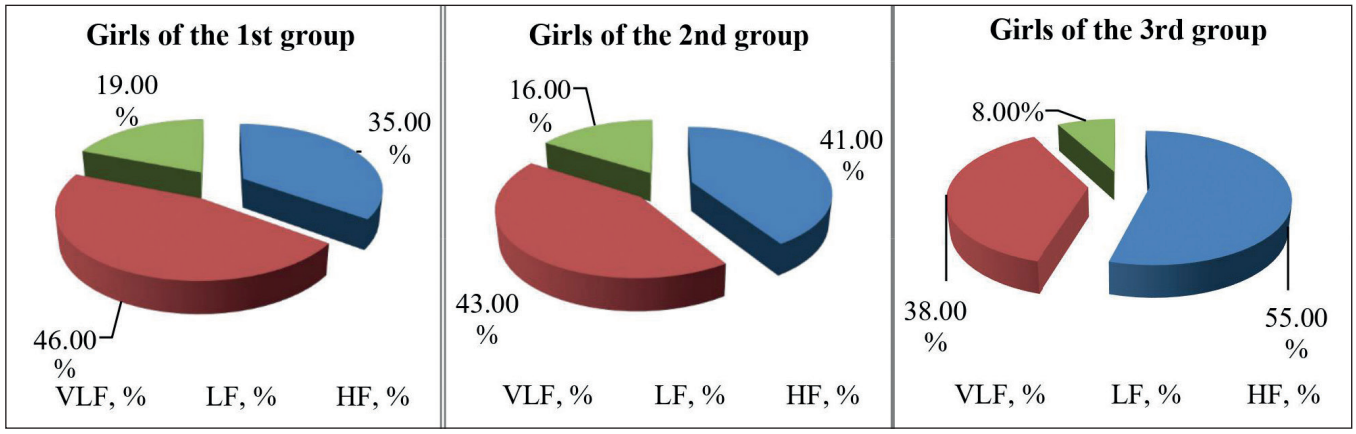

Fig. 2. The relationship between the ANS effect pathways on heart rhythm in groups of middle school-aged children with different values of BMI.

Although the highest absolute values of VLF ms^2, LF ms^2, and HF ms^2 were recorded in children with normal body weight as compared to children with excessive body weight and obesity, the relative values of these indicators differed. The highest value of the fractional contribution of the power in the very low frequency range (VLF) to the TP was found in children with obesity (53,4±3,9%), a slightly lower value was found in children with excessive body weight (41,0±2,7%), and the lowest value was recorded in children with normal body weight (35,4±3,1%). However, the fractional contribution of the power in the high frequency range (HF) to the TP was the lowest in obese children (8,4±2,7%), and practically equal in children with normal and excessive body weight (18,6±2,4% and 15,8±3,6% respectively). The fractional contribution of the low frequency range (LF) to the TP in children with different BMI values was as follows: group 1: 46,0±2,7%, group 2: 43,2±4,7%, and group 3: 38,2±2,5%.

The analysis of the contribution of the frequency components of the TP to the structure of the heart rhythm modulation within each group revealed that the wave structure of heart rhythm in children with normal and excessive body weight was LF> VLF> HF, while in obese children it was VLF> LF> HF.

During the transition from the clino- to the orthoposition, differences were also found in the value of the Cr indicator among girls of different constitution. Thus, representatives of groups 2 and 3 had an accelerated type of heart rate response to changes in body position compared with those of the first group. It also indicates on the autonomic dysfunction due to excessive activation of the sympathetic ANS in these individuals.

DISCUSSION

The comparison of HRV indices between the groups of children shows that obese girls have abnormalities in the functioning of some systems, in particular of the cardiovascular and regulatory systems, and in their adaptation abilities.

The analysis of the levels of tension of the regulatory systems showed that the sum of PARS points in girls of the 3rd group averaged 5,478± 1,581 units, which exceeds the normal value of this indicator and points to the presence of premorbid state in subjects of this group. This is manifested by the tension of the regulatory systems, decreased functional reserves and the beginning of the development of energy and metabolic imbalance [13].

The evaluation of the indicator of the total activity of the regulatory systems in girls of the same group revealed a decrease in the total power of the spectrum (TP) (1822±212 ms^2), the normal value of which is within 1906-5790 ms^2 [14]. Overall, the neurohumoral regulation in subjects in this group was characterized as VLF> LF> HF. Relative to the total power, VLF accounted for 55%, LF - for 38%, and HF – for only 8%. This proportion reflects an increased level of humoral and metabolic influences in modulation of heart rhythm and a decreased level of parasympathetic influence. Because VLF index is a sensitive indicator of the regulation of metabolic processes and reliably reflects energy-deficient states, the predominance of its influence in heart rhythm modulation points to the tension of regulation mechanisms and depletion of adaptation resources [13].

The analysis of spectral indices of the vagosympathetic balance (LF/HF) in obese girls also suggests the domination of sympathetic influences and a decrease of vagus activity in relation to the cardiovascular system, and a decrease of the central control loop activity. This can be regarded as a prognostically unfavorable risk factor [15]. The lowest absolute values of VLF ms^2, LF ms^2 and HF ms^2 in the 3rd group compared to the 1st and 2nd groups also indicate a significant preponderance of the role of the sympathetic branch of the ANS over its parasympathetic branch.

Therefore, our study revealed that obese girls have a decreased activity of the parasympathetic nervous system and an increased activity of the sympathetic nervous system, which can be considered as an increased tension of the adaptation mechanisms, a decrease of reserve capacities, and the development of functional autonomic disturbances with their further transformation. Our data is confirmed by the results of the research on this problem, namely, those showing that BMI in obese children is negatively associated with HF, and positively associated with LF and the HF/LF ratio [16].

CONCLUSIONS

Obese girls exhibited disturbances in the functional state of the ANS towards sympathicotony and increased functional activity of the suprasegmental ANS divisions, which can be interpreted as an autonomic dysfunction.

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