ORIGINAL ARTICLE

CORRECTION OF AUTONOMIC DYSFUNCTION IN OVERWEIGHT CHILDREN BY NORMALIZING BODY COMPOSITION

DOI: 10.36740/WLek202210112

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ABSTRACT

The aim: To investigated the effect of a 3-month body weight correction program on the functional state of the ANS in children of primary school age who had an increased body mass index and signs of autonomic dysfunction.

Materials and methods: 82 children aged 9 to 11 were examined. During 3 months, all examinees underwent a body weight correction course. Body composition was measured by the bioimpedance method using the body composition analyzer «TANITA-BC-601» (Japan). The functional state of autonomic regulation was assessed using heart rate variability (HRV) indicators obtained by recording standard 5-minute ECG intervals using the computer hardware and software complex "CARDIOLAB" (XAI-MEDICA, Ukraine).

Results: Statistical processing of HRV indicators showed that 51 children (62.2%) had signs of autonomic dysfunction. In the first group, there was a statistically significant decrease in body weight (from 47.33±4.62 to 44.12±3.96), BMI (from 28.15±2.64 to 26.63±2.87), TFC (from 33.54±3.68 to 30.89±2.81), VF (from 7.056±1.814 to 4.817±2.017) with a simultaneous statistically probable increase in the FFM index (from 60.27±2.47 to 63.15±2,38). According to the time domain indicators of HRV, children in first group have increased the TP of autonomous heart rhythm regulation, as indicated by a statistically significant increase in SDNN from 38.43±6.39 ms to 51.65±7.19 ms ($p<0.05$); the activity of the sympathetic link of the ANS decreased according to AMo from 41.23±6.17% to 34.29±5.83% ($p<0.05$) and the intensity of autonomic regulation according to IS, which decreased from 116.3±31,6 units to 81.2±29.1 units ($p<0.05$).

Conclusions: 3-month body weight correction program led to the elimination of signs of autonomic dysfunction in 43.9% of the examined persons.

KEY WORDS: autonomic dysfunction, body composition, overweight children, heart rate variability

Wiad Lek. 2022;75(10):2386-2391

INTRODUCTION

Obesity among school-aged children has reached the scale of a global epidemic both in our country and abroad [1], and its prevalence remains high, despite the enormous efforts made by doctors and educators to stabilize the situation [2]. It is known that obesity in childhood is associated with a number of metabolic, cardiovascular and other disorders, which include dyslipidemia, type 2 diabetes, lung disorders, blood system pathology [3]. Since dysfunction of the autonomic nervous system (ANS) can contribute to the development or stabilization of obesity and is associated with cardiovascular mortality [4], studying the functional state of the ANS in obesity is of significant clinical interest. The majority of studies of autonomic dysfunction in children with obesity relate to the assessment of autonomic regulation of heart function by analyzing heart rate variability (HRV), which is considered a kind of diagnostic window into the functional state of the ANS as a whole. These studies generally found a decrease in parasympathetic activity. However, it remains unclear how significant the changes in the sympathetic chain of the ANS are in overweight and obese children and adolescents. It is considered proven that autonomic dysfunction increases the load on the cardiovascular system, aggravates hemodynamic stress, serious heart rhythm disorders and other cardiac pathology. Thus, cardiac autonomic imbalance may also be an important link between obesity and increased morbidity and mortality.

THE AIM

It was established that autonomic disorders in overweight adults are subject to reverse development under the condition of weight loss. Because autonomic imbalance is a marker of adverse risk, improvements derived from weight loss should also benefit the health of overweight and obese children. To test this assumption, we investigated the effect of a 3-month body weight correction program on the functional state of the ANS, assessed by heart rate variability, in children of primary school age who had an increased body mass index and signs of autonomic dysfunction.

MATERIALS AND METHODS

82 children aged 9 to 11 were examined, of which 38 were boys and 43 were girls. All examined children were in the pre-pubescent period of development without clinical signs of pathology according to physical examination

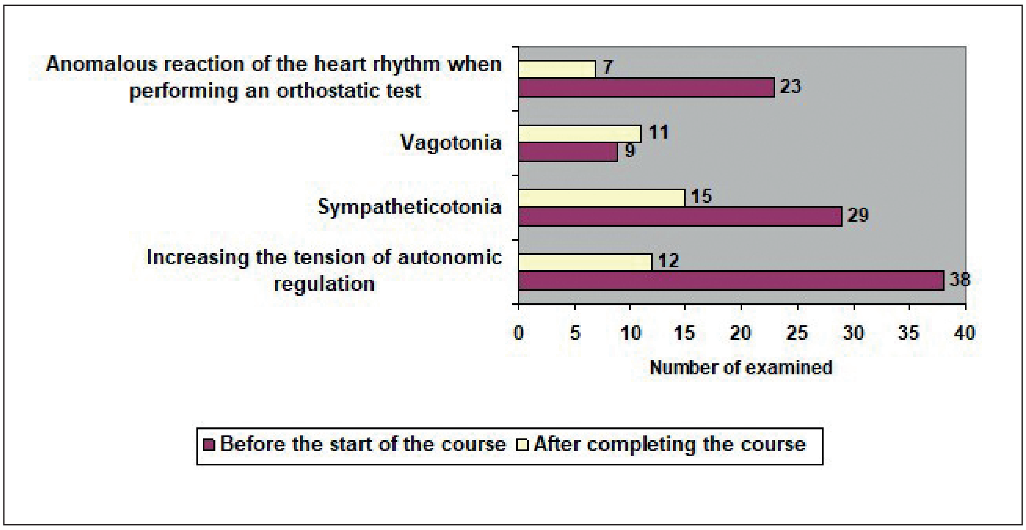

Fig. 1. Dinamics of the number of eximinees with sings of autonomic dysfunction under the influence of a 3-months course of body weight correction

and laboratory tests (general blood and urine analysis, biochemical blood analysis, blood pressure indicators). The criterion for inclusion in the study was the presence of excess body weight according to the criterion of body mass index (BMI) in the range of 25.0-29.9 kg/m^2. Individuals with clinical signs of obesity or metabolic syndrome were excluded from the study.

During the next 3 months, all examinees, under the guidance of an instructor, underwent a body weight correction course, which included the formation of healthy eating skills with the selection of individual caloric content of the diet and physical activity of a high-speed and strength nature (dance and gymnastic exercises, sports games) with a frequency of 3 training sessions per week lasting 45-60 minutes.

The examination was carried out before the beginning and at the end of the course and included the assessment of body composition by the bioimpedance method using the body composition analyzer «TANITA-BC-601» (Japan). In particular, the following were determined: body weight (W, kg.), body mass index (BMI, kg/m^2), total fat content (TFC, %), visceral fat rating (VF, units), fat-free mass content (FFM, %). The functional state of autonomic regulation was assessed using heart rate variability (HRV) indicators obtained by recording standard 5-minute ECG intervals using the computer hardware and software complex «CARDIOLAB» (XAI-MEDICA, Ukraine) according to the generally accepted method [5]. In particular, the time characteristics of the heart rhythm were determined: indicators of the general variability of the heart rate: SDNN, ms – standard deviation of all RR intervals of a 5-minute ECG interval, indicators of parasympathetic ANS activity (RMSSD, ms – square root of the average value of the squares of the differences in the lengths of consecutive RR intervals, pNN50, % is the percentage of adjacent RR intervals, the difference between which exceeds 50 ms.). In the spectral analysis of HRV, the following parameters were used: TP, ms^2 – the total power of the heart rhythm spectrum; VLF, ms^2 – the power of the spectrum of very low frequencies (central neurohumoral influences); LF, ms^2 – the power of the spectrum of low frequencies (reflecting the activity of the sympathetic link of the ANS); HF, ms^2 – the power of spectral high frequencies (reflect the activity of the parasympathetic link of the ANS); LF/HF – an indicator of sympatho-vagal balance (sympatho-parasympathetic index). In addition, the percentage contribution of frequency components of the spectrum to TR (VLF%, LF%, HF%) was calculated. The reactivity of the peripheral link of the ANS was evaluated based on the results of an orthostatic test with the determination of the reaction coefficient (K 30:15), which is calculated as the ratio of the maximum value of the R-R interval (usually around the 30th contraction of the heart after the transition to a vertical position) to the shortest R – R-interval corresponding to the 15th cardiac contraction.

In addition to standard indicators, the following were also determined: the index of centralization (IC), which reflects the relationship between the autonomous and central circuits of heart rhythm regulation, the index of tension of regulatory systems (IS), which characterizes the degree of centralization of heart rhythm control. MS Excel statistical package was used for statistical processing of the research results. The difference between the studied samples was evaluated using non-parametric methods (ANOVA) and the Student's t-test for two independent samples.

RESULTS

Statistical processing of HRV indicators in the entire sample of the examined showed that 51 children (62.2%) had signs of autonomic dysfunction (Table I). These signs included: an increase in the intensity of autonomic regulation, the criterion of which was the total power of the heart rhythm spectrum (TP) and the standard deviation of all RR intervals of a 5-minute ECG interval (SDNN) output beyond the lower limit of the norm for this age category; sympathicotonia or vagotonia according to the deviation from the norm of the sympatho-vagal balance indicator (LF/HF); anomalous reaction of the heart rhythm when performing an orthostatic test, estimated by the reaction coefficient (K 30:15). The sum

Table I. The distribution of examined children depending on the presence of autonomic dysfunction

№	A type of autonomic dysfunction	Absolute number	Percentage of all examined
1	Increasing the tension of autonomic regulation	38	46,3
2	Sympatheticotonia	29	35,4
3	Vagotonia	9	11,0
4	Anomalous reaction of the heart rhythm when performing an orthostatic test	23	28,0
5	Absent	31	37,8
6	All examined	82	100

Table II. The dynamics of indicators of the component composition of the body of the examined persons under the influence of a 3-month course of body weight correction (M+m)

Indicators of the component composition of the body	Group 1 (n=51)		Group (n=31)	
	Before the start of the course	After completing the course	Before the start of the course	After completing the course
BMI, kg/m^2	28,15±2,64	26,63±2,87*	27,96±2,82	25,94±2,66**
TFC, %	33,54±3,68	30,89±2,81*	32,81±3,75	29,99±2,76*
VF, units	7,056±1,814	4,817±2,017**	6,573±1,722	3,832±2,118**
FFM, %	60,27±2,47	63,15±2,38*	61,03±2,24	63,34±2,19*
Body weight, kg	47,33±4,62	44,12±3,96*	46,98±4,71	43,32±4,06*

Note: Differences are statistically significant at level * - p≤0,05; ** p≤0,01

Table III. The dynamics of indicators of the component composition of the body of the examined persons under the influence of a 3-month course of body weight correction (M+m)

HRV indicators	Group 1 (n=51)		Group 2 (n=31)	
	Before the start of the course	After completing the course	Before the start of the course	After completing the course
SDNN, ms	38,43±6,39	51,65±7,19*	50,82±14,37	55,53±16,87
TP, ms^2	3122±695	3959±675*	3099±1034	3867±1445
LF, ms^2	1305±264	1033±218*	705±364	956±418
AMo, %	41,23±6,17	34,29±5,83	40,55±10,07	37,67±6,83
RMSSD, ms	17,95±2,15	31,22±3,81**	35,19±4,15	41,28±4,82*
pNN50, %	6,79±2,45	15,28±4,11	16,82±6,55	25,09±7,12*
HF, ms^2	878±288	1236±345	803±281	1045±448
VLF, ms^2	939±351	1690±448	1591±752	1866±748
LF/HF	1,49±0,74	0,84±0,48**	0,88±0,77	0,91±0,58
IC	4,39±2,81	4,56±3,15	4,56±2,84	4,23±3,16
IS	116,3±31,6	81,2±29,1*	119,1±42,5	88,4±32,4*
VLF %	30,08±5,74	42,69±6,71**	51,34±11,21	48,25±10,35
LF, %	41,89±7,12	26,09±5,79**	22,75±10,98	24,72±5,09
HF, %	28,12±4,02	31,22±5,70	25,91±4,77	27,02±6,76

Note: Differences are statistically significant at level * - p≤0,05; ** p≤0,01

of all types of autonomic disorders in the table exceeds the total number of persons with these disorders, as some of them combined 2-3 of the identified signs of autonomic dysfunction. In this regard, all examinees were divided into two groups: group 1, which included 51 overweight individuals with signs of autonomic dysfunction, and group 2, which included 31 overweight individuals without signs of autonomic dysfunction according to HRV.

In the table II shows the dynamics of indicators of the component composition of the body in the examined children of both groups under the influence of the 3-month body weight correction program. In both groups, there were significant changes in body weight, BMI, TFC, VF, and FFM. In the first group, there was a statistically significant decrease in body weight (from 47.33±4.62 to 44.12±3.96), BMI (from 28.15±2.64 to 26.63±2.87), TFC (from 33.54±3.68 to 30.89±2.81), VF (from 7.056±1.814 to 4.817±2.017) with a simultaneous statistically probable increase in the FFM index (from 60.27±2.47 to 63.15±2 ,38). Similar changes occurred in the examined children of the 2nd group. Thus, their body weight decreased from 46.98±4.71 to 43.32±4.06; BMI from 27.96±2.82 to 25.94±2.66; TFC from 32.81±3.75 to 29.99±2.76; VF from 6.573±1.722 to 3.832±2.118 with a simultaneous statistically probable increase in the FFM indicator from 61.03±2.24 to 63.34±2.19. It is worth noting that even after the positive dynamics of the body composition indicators of the subjects in both groups, they did not reach the normative values for children of the corresponding age and sex.

The dynamics of HRV indicators under the influence of a 3-month course of body weight correction is presented in Table III. Statistical processing of the obtained data showed that similar changes in the functional state of the ANS occurred in both groups of subjects. However, these changes were more pronounced in children of the 1st group. Thus, according to the time domain indicators of HRV, they have increased the TP of autonomous heart rhythm regulation, as indicated by a statistically significant increase in SDNN from 38.43±6.39 ms to 51.65±7.19 ms ($p<0.05$); the activity of the sympathetic link of the ANS decreased according to AMo from 41.23±6.17% to 34.29±5.83% ($p<0.05$) and the intensity of autonomic regulation according to IS, which decreased from 116.3±31,6 units to 81.2±29.1 units ($p<0.05$). At the same time, indicators characterizing the activity of the parasympathetic part of the ANS significantly increased. This applies to RMSSD, which increased from 17.95±2.15 ms to 31.22±3.81 ms ($p<0.01$) and pNN50, which increased from 6.79±2.45% to 15.28± 4.11% ($p<0.01$).

This nature of changes in the functional state of the ANS is also confirmed by the dynamics of the HRV spectral parameters. In particular, the total power of autonomous heart rhythm regulation according to TP increased from 3122±695 ms^2 to 3959±675 ms^2 ($p<0.05$); the power of low-frequency LF waves decreased from 1305±264 ms^2 to 1033±218 ms^2 ($p<0.05$); the power of very low frequency VLF waves increased from 939±351 ms^2 to 1690±448 ms^2 ($p<0.05$). The absolute value of the indicator of the activity of the parasympathetic link of the HF did not change statistically reliably, although the indicator of the sympatho-parasympathetic balance LF/HF decreased from 1.49±0.74 to 0.84±0.48. The most vivid redistribution of the activity of the peripheral part of the ANS in favor of the parasympathetic link was manifested in the dynamics of the relative contribution of the indicators of the sympathetic link (LF%) and the range of segmental levels of regulation (VLF%) to the total power of the wave spectrum of the heart rhythm (TR). Thus, LF% decreased from 41.89±7.12% to 26.09±5.79% ($p<0.01$), while VLF% increased from 30.08±5.74% to 42 .69±6.71% ($p<0.01$).

In the examined subjects of the 2nd group, the dynamics of changes in HRV indicators was similar in direction to similar changes in the 1st group, but for most parameters it was not statistically reliable. The exception was the time indicators characterizing the activity of the parasympathetic link of the ANS and the stress index of autonomic regulation (IS). In particular, the RMSSD in the examinees of this group increased from 35.19±4.15 ms to 41.28±4.82 ms ($p<0.05$); pNN50 increased from 16.82±6.55% to 25.09±7.12% ($p<0.05$), and IS decreased from 119.1±42.5 to 88.4±32.4 ($p <0.05$).

As a result of the redistribution of the functional activity of various links of the ANS in the examined persons of the 1st group under the influence of the course of body weight correction, the total number of children with autonomic dysfunction decreased from 51 to 15 persons, or in relative figures from 62.2% to 18.3% of all examined (Fig. 1). The biggest changes occurred in the number of children with increased tension of autonomic regulation (from 38 to 12) and with an abnormal heart rate response during the orthostatic test (from 23 to 7).

DISCUSSION

Childhood obesity is a complex syndrome that is ultimately the result of the interaction of many factors, including genetics, prenatal experiences, family and cultural traditions, emotional factors, and levels of physical activity [6-9]. In a number of studies of obese adults, the presence of autonomic nervous system dysfunction is noted [10-12]. However, the connection between obesity and the function of the ANS cannot yet be considered completely clarified. Studies of the functional state of the ANS in overweight and obese children compared to studies of adults are few. That is why clarifying the relationship between indicators of the component composition of the body and autonomous regulation in children of primary school age with excessive body weight is an urgent scientific problem. From the data we obtained, it follows that about 60% of such children have signs of autonomic dysfunction. The most frequent forms of such dysfunction were an increase in the intensity of autonomic regulation, which was expressed in a decrease in the heart rate variability according to the mean square deviation of the ECG cardio intervals (SDNN) and the total power of the heart rate spectrum (TP), as well as abnormal reactivity of the ANS to the orthostatic test.

A detailed analysis of the HRV indicators of the studied contingent revealed a change in the activity of both the sympathetic and parasympathetic links of the ANS. In general, the results obtained by us indicate a tendency towards excessive activation of the sympathetic link of the ANS and simultaneous suppression of the parasympathetic link. To the best of our knowledge, no previous similar studies have been conducted in elementary school-age children who are overweight but without clinical signs of obesity. Studies of ANS in obese adults report conflicting findings. Some of them demonstrate hypoactivity of the parasympathetic nervous system [9,10], which was also found in our study. Some others have demonstrated dysfunction of both the sympathetic and parasympathetic branches of the ANS, or only dysfunction of the sympathetic branch [11,12]. These discrepancies may result from the use of different methods in different studies.

In several studies, the authors provided evidence of autonomic dysfunction in obese children. In particular, there were signs of a decrease in vagal activity of heart rate variability [13-15,18] with some reports of a simultaneous decrease in sympathetic activity [17,19]. The ratio of low-frequency to high-frequency waves may also be increased in obese children [14, 15], which is a marker of sympathovagal imbalance [17]. These data coincide with the results of our study. In addition, a decrease in baroreflex sensitivity was also reported [21]. Given that the baroreflex is important for blood pressure regulation, assessment of cardiac baroreceptor sensitivity includes both afferent and efferent signaling in cardiac vagal activity and may be more sensitive than heart rate variability for detecting autonomic dysfunction in children.

Based on the hypothesis of a close relationship between the accumulation of fat in the body and autonomic disorders, it is logical to assume that the normalization of body composition can contribute to the elimination of these disorders. A proven method of correcting the component composition of the body in overweight children is a healthy diet and dosed physical aerobic activity. It is known that overeating and eating food with a high glycemic index is the main cause of obesity [5]. The centers of appetite and satiety in the hypothalamus play a key role in the regulation of eating behavior [2,5]. On the other hand, it is known that the hypothalamus controls the functions of the ANS. Therefore, we believe that teaching a child healthy eating skills eliminates a possible pathogenetic mechanism of the formation of autonomic dysfunction. This is evidenced by the dynamics of autonomic disorders in the group of children who underwent a 3-month body weight correction course. In particular, the percentage of children with signs of autonomic dysfunction decreased from 62.2% to 18.3%.

Physical activity is a key element in the prevention and treatment of obesity and diabetes in children. Regular physical activity effectively supports weight loss achieved through a healthy diet, improves glycemic control, and can prevent or delay the diagnosis of type 2 diabetes. In addition, physical activity has a positive effect on the lipid profile, blood pressure, reduces the frequency of cardiovascular disorders and related mortality, and also restores the quality of life in type 2 diabetes [22]. Obesity in combination with diabetes is characterized by hyperactivity of the sympathetic link of the ANS and a progressive decrease in parasympathetic control of the heart. They manifest through various pathogenetic mechanisms, including hyperinsulinemia, visceral obesity, subclinical inflammation, and increased thrombosis. That is why we consider it necessary to include in the body weight correction program and regular aerobic exercises in the form of dance and gymnastic exercises and sports games.

CONCLUSIONS

1. Among elementary school-aged children with excess body weight (BMI in the range of 25.0-29.9 kg/m^2), 62.2% had signs of autonomic dysfunction in the form of increased tension of autonomic regulation, sympathicotonia or vagotonia according to deviations from the norm an indicator of sympatho-vagal balance, an abnormal reaction of the heart rhythm when performing an orthostatic test.
2. The application of a 3-month body weight correction program (teaching healthy eating skills and regular physical activity in the form of dancing and gymnastic exercises and sports games) led to the elimination of signs of autonomic dysfunction in 43.9% of the examined persons.

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The research was carried out within the framework of the scientific project "Functional state of autonomic systems depending on the correlation between adipose and muscle tissue in normal and pathological state" (state registration number: 0118U000713)

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Conflict of interest:
The Authors declare no conflict of interest.

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Received: 08.04.2022
Accepted: 02.09.2022

A – Work concept and design, **B** – Data collection and analysis, **C** – Responsibility for statistical analysis, **D** – Writing the article, **E** – Critical review, **F** – Final approval of the article