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Comprehensive Therapy of Children with Abdominal Obesity and Metabolic Syndrome Using Transcranial Physiotherapy

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Abstract **Introduction.** Despite diet, work with a psychologist, lifestyle changes, most children with obesity have insufficient motivation to lose weight, which is accompanied by a short-term decrease in body weight. These facts contribute to the search for effective and safe treatment methods applicable to children. **The aim of the study**: to evaluate the effectiveness of the combined use of ά-lipoic acid, vitamin D, transcranial magnetic therapy and electrical stimulation in the treatment of children with abdominal obesity and manifestations of metabolic syndrome. **Materials and methods**: 128 children with abdominal and generalized obesity were studied, the state of carbohydrate and lipid metabolism, the level of vitamin D, leptin, ghrelin and peptide YY3-36 were determined. Various methods of therapy were used with the use of ά-lipoic acid, vitamin D, transcranial magnetic therapy and electrical stimulation. **Results of the study**: children with abdominal obesity and generalized obesity had significant pathology of carbohydrate and lipid metabolism with more severe manifestations in children with visceral obesity. Obesity in children is accompanied by a significant increase in basal leptin production, a decrease in fasting ghrelin secretion and peptide YY3-36, while the degree of pathology of these indicators depended on the type of obesity. The frequency of MS in children with abdominal obesity was 54.5%, while all children had vitamin D deficiency. **Conclusion:** When using ά-lipoic acid, vitamin D, transcranial magnetic therapy and electrical stimulation against the background of motivational training for weight loss, positive dynamics are determined in reducing eating behavior, biochemical parameters, levels of anorexigenic and orexigenic hormones in the following group of studies.

Keywords Children, Abdominal obesity, Metabolic syndrome, ά-lipoic acid, vitamin D, Transcranial magnetic therapy, Electrical stimulation

1. Introduction

According to the World Health Organization, obesity is a global problem of world society that deserves close attention. It is important that the obesity epidemic is spreading at an alarming rate among children [1,2,3].

The development of obesity in childhood contributes to the development of a high risk of early manifestation of severe comorbid conditions with the formation of metabolic syndrome (MS), which is a factor in reducing life expectancy and contributes to premature mortality in adulthood [4,5,6]. In this regard, the prevention and treatment of obesity and its complications are of great clinical importance and social significance.

Successful treatment of obesity and its complications in children is possible only with complex and long-term therapy aimed at changing the lifestyle of the child and his family members, changing the diet, promoting physical activity, as well as psychological assistance that helps prevent or treat eating disorders [6,7,8].

Despite diet, work with a psychologist, lifestyle changes, most children with obesity have insufficient motivation to lose weight, which is accompanied by a short-term decrease in body weight. These facts contribute to the search for effective and safe treatment methods applicable to children.

Such methods of therapy include the use of alpha lipoic acid, which has a good therapeutic effect without disrupting homeostasis in the body, normalizing metabolic processes, this is especially important to consider in childhood. The hypoglycemic effect of alpha lipoic acid is known with an increase in tissue sensitivity to insulin, and intracellular glucose transport and, as a result, insulin resistance decreases. α-lipoic acid also reduces the formation of cholesterol and its atherogenic fractions [9,10,11].

Thus, alpha lipoic acid influences all factors that determine the overall risk of developing carbohydrate and lipid metabolism disorders that form metabolic syndrome.

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Literary data indicate that the use of only traditional therapy in children with manifestations of MS is insufficient, in connection with which the method of physiotherapeutic transcerebral influence was used.

The impact on central regulatory mechanisms is an important component in the treatment of obesity. Correction of the mechanisms of the hypothalamic-pituitary-endocrine gland system by pharmaceutical means is practically impossible, since the blood-brain barrier prevents the action of drugs. This contributed to drawing attention to physiotherapeutic approaches that affect the structures of the brain. Among physical factors, the best is the magnetic field: it easily penetrates tissues, does not have a warming effect, is a natural factor, has vasodilatory, antispasmodic, hypotensive, anti-edematous, neurotrophic and immunomodulatory properties [6,13,14]. Complex treatment of patients with adolescent hypothalamic syndrome using transcranial magnetic therapy (TcMT) has achieved significant positive results. Recently, combined physiotherapeutic methods with a unidirectional effect have been considered more effective. From this point of view, it is recommended to combine TcMT with transcranial electrical stimulation (TES), the main effect of which is to increase endogenous opioids, especially endorphins, in the blood, which can make it easier for the patient to change his or her eating behavior.

The relevance of the problem of prescribing increased doses of vitamin D to children with concomitant pathology in the form of obesity and overweight in children is still being discussed in many countries to this day [15].

In children and adolescents with obesity, the use of vitamin D to initiate weight loss gives very contradictory results, but its use has been proven to reduce the risk of negative consequences of excess weight [16]. A consensus has been reached regarding the need for mandatory administration of vitamin D preparations in children and adolescents with obesity, but there are no generalized standards for daily dosage and duration of therapy [17].

Taking into account the above data, we set the following **research objective**: to evaluate the effectiveness of the complex use of ά-lipoic acid, vitamin D, transcranial magnetic therapy and electrical stimulation in the treatment of children with abdominal obesity and manifestations of metabolic syndrome.

2. Material and Methods

The studies were conducted at family clinics in the city of Samarkand, as well as Samarkand regional branch of the Republican specialized endocrinology scientific and practical medical center named after academician E.H. Turakulov (Uzbekistan).

The study involved 128 children aged 8 to 18 years with exogenous-constitutional obesity, with an average age of 12.11±0.61 years. The control group consisted of 40 children of the same age (12.19±0.18) with body weight having normal indicators, all children had no chronic diseases and acute diseases at the time of examination.

Anthropometric studies were conducted using standard measuring devices. Anthropometric measurements include height, weight, waist and hip circumference. Comparison of the obtained data and assessment of physical development were performed using WHO age and gender distribution centile charts of height and weight for children aged 5-19 years [18]. Body mass index (BMI) was calculated using the generally accepted formula.

At the initial examination stage, anthropometric studies were conducted and assessed using standard deviations of the body mass index (SDS) in accordance with the recommendations of the World Health Organization (WHO) [18]. The basis for establishing the diagnosis of obesity was the determination of the intersection point of age and BMI above +2.0 SDS BMI [1].

In accordance with the set objectives, the children of the main group were divided into 2 main groups: Group 1 - 60 children with abdominal obesity, had a BMI of +2.0 to ≥+3 SDS (obesity from I-III degree).

Waist circumference in this group exceeded the 90th percentile for the corresponding age and gender. The average BMI in children of this group (32.89±0.61 kg/m^2) significantly exceeded the indicators of the control group ($p<0.001$).

Group 2 - 68 children with a generalized type of obesity, also included patients with a BMI of +2.0 to ≥+3 SDS, (obesity group I-III) but with WV within the normal range according to percentile deviations according to age and gender. On average, BMI was 31.99±0.45 kg/m^2.

The control group consisted of 40 children of the same age (on average 12.00±0.21 years) with normal body weight of 19.36±0.28 kg/m^2 (BMI less than +1 SDS for a given gender and age).

All children in the main sample had their WV and HV determined, with subsequent determination of the WV/HV ratio, which served as an objective indicator of the presence or absence of abdominal obesity. WV was correlated with the WV percentile tables for gender and age, and abdominal obesity was diagnosed with WV values corresponding to the 90th percentile and above for a given age and gender [19]. For children aged 16 years and above, the criterion was WV ≥ 94 cm for boys and ≥ 80 cm for girls.

The results showed that in children with abdominal obesity, the WV was within 102.12±1.52 cm, which was significantly higher compared to the control group 65.54±0.80 cm ($p<0.001$), and children with generalized obesity 81.32±0.15 ($p<0.001$). At the same time, the HV in children with abdominal obesity was (86.11±2.11 cm) and did not differ from the indicators of children in the control group (78.23±1.22 cm; $p>0.05$). The WV/HV ratio characterizing the presence of abdominal obesity averaged 1.02±0.01 cm ($p<0.001$ compared to the control and comparison group) and in children with a generalized type of obesity 0.92±0.00 cm ($p<0.001$), in the control 0.79±0.01 cm.

Blood pressure was measured using the Korotkov method, using cuffs of different lengths, corresponding to the circumference of the children's arm. To diagnose AH

in obese children, special tables were used, based on the results of studies of the population of children, taking into account the age, sex and height of the child [19].

Plasma glucose level was estimated by glucose oxidase method using GLUCL reagent kit for Abbott Architect 8000 analyzer. Serum insulin level was estimated using enzyme immunoassay method, reagent kit and calibrators manufactured by Roche Diagnostics ELECSYS Insulin. (Germany) for Cobas e411 analyzer. Standard oral glucose tolerance test (OGT, glucose load 1.75 g/kg, no more than 75 g) was performed with measurement of fasting glucose level (glucose 0') and 120 minutes after glucose load (glucose 120'). Insulin resistance index (HOMA-IR) was calculated by the formula: fasting insulin (pmol/l) × fasting glucose (mmol/l)/155. Values less than 3.2 were taken as normative $HOMA_R$ index.

The lipid profile was studied on an automatic biochemical analyzer Cobas Integra 400 plus (Roche, Germany) using original test systems (Roche, Germany) with the determination of concentrations of total triglycerides, high-density lipoprotein cholesterol by absorption photometry.

Determination of leptin, ghrelin and YY3-36 was carried out by the enzyme immunoassay method on the HumaReader HS device, using the Human LEPTIN ELISA Kit, Human GHRL (Grelin) ELISA Kit, ELISA DSL-10-33600 test systems (manufactured by Elabscience USA).

Transcranial magnetic therapy (TMT) and transcranial electrical stimulation (TES) were used using the AMO-ATOS-E device (LLC Trima, Saratov; registration certificate № FSR 2009/04781). Considering that physical impact is better absorbed by the body if its frequency parameters are close to the frequencies of the functioning of the main body systems, magnetotherapy with a running magnetic field was carried out in the scanning frequency range of 1–12 Hz. Sessions with the "Headband" attachment were carried out with the patient in a sitting position. Induction on the surface of the emitter was 20–45 mT (depending on age). Impact with a running magnetic field was carried out from the temporal lobe to the occipital lobe synchronously on both hemispheres of the brain for 7–12 min. The modulation frequency and exposure time were gradually increased with each procedure, starting with the minimum values. In the last sessions, the regular scanning mode was replaced by the "Stochas" mode. TES was carried out with an output voltage of 15–20 V and an average current of no more than 25 mA. Pulse packs followed with a frequency of 50–80 Hz. The course of treatment consisted of 15 daily procedures [13].

As part of the complex therapy of children with manifestations of MS, α-lipoic acid was used at 100 mg 3 times a day for children under 14 years old, 200 mg 3 times a day for children over 14 years old for 1 month. Cholecalciferol was used in a dosage in accordance with the SDS of the BMI. In children with a BMI of +1.0 to +2.0 SDS, vitamin D was used at a daily dose of 2000 U/day, BMI >+2<+3 SDS at a daily dose of 3000 U/day and in children with a BMI ≥+3 SDS at a dose of 4000 U/day for 3 months.

Statistical processing of the obtained data was carried out on a personal computer using the Statistica 10 program. The methods of variational parametric and nonparametric statistics were used with the determination of the arithmetic mean (M), standard deviation (σ), standard error of the mean (m), relative values (frequency, %). The statistical significance of the obtained measurements was determined by the Student criterion (t) with the calculation of the probability of error (P). Correlation analysis by the Pearson method (r).

3. Results and Their Discussion

The metabolic status of children was identified by determining the level of carbohydrate and lipid metabolism. Comparative characteristics of the average level of the obtained result showed that children with abdominal obesity had the highest pathological results compared to children with a generalized type of obesity. At the same time, the average results of the metabolic indicators did not go beyond the reference limits (Table 1).

Levels of adipose tissue hormone and gastrointestinal hormones, among which leptin, peptide YY3-36 and ghrelin play an important role, have a leading effect on the feeling of hunger and satiety [21,22,23].

It was found that in children with abdominal obesity, the leptin level had higher values compared to children with a generalized type of obesity, amounting to 27.16±0.71 ng/ml, versus 19.68±1.02 ng/ml ($p<0.0000$), while the state of leptin resistance, an increase in the leptin level above 26 ng/ml was noted in 75% of children with a visceral type of distribution of adipose tissue, and in 46.6% of children with a generalized type of obesity.

In contrast, the levels of the hormone ghrelin and peptide YY3-36 tended to decrease in children with abdominal obesity compared to generalized obesity (8.12±0.38 pg/ml and 75.52±2.0 pg/ml with abdominal obesity; 9.08±0.30 pg/ml and 86.01±2.60 pg/ml with generalized obesity).

We were interested in studying the indicators of additional criteria characterizing MS, to which the level of vitamin D has recently been attributed. It was revealed that the condition characterizing vitamin D deficiency was observed in 76.5% of children with abdominal obesity, while in children with a generalized type this condition was observed in less than 46.7% ($p < 0.01$), the condition of vitamin D deficiency was observed in 23.5% of children with visceral obesity and 45.0% in children with a generalized type of obesity. In children with abdominal obesity, there were no cases with normal vitamin D levels, whereas in children with generalized obesity, normal vitamin D levels were observed in only 8.3% of children.

The average level of vitamin D was also statistically the lowest in children with abdominal obesity (19.41±0.74 ng/ml), falling within the limits characterizing vitamin D deficiency; in children with generalized obesity, the average levels of cholecalciferol were within the limits of deficiency of this vitamin (23.11±0.52 ng/ml).

Table 1. Average indices of carbohydrate and lipid metabolism, hormonal status in comparison groups

Carbohydrate metabolism indicators	Control group n= 40	Group I n= 68	Group II n= 60
Fasting glucose; mmol/l	4,00±0,10	5,18±0,12 P_1<0,001	4,98±0,11 P_1<0,001
Insulin (pmol/l)	18,16±0,79	69,72±4,69 P_1<0,001; P_2<0,001	45,03±4,13 P_1<0,001
Index IR NOMA $_R$ (s. units)	0,47±0,01	2,15±0,16 P_1<0,001; P_2<0,03	1,68±0,16 P_1<0,001
Triglycerides; mmol/l	0,75±0,04	1,29±0,03 P_1<0,01; P_2<0,05	1,00±0,05
HDL- cholesterol; mmol/l	1,33±0,03	1,02±0,01 P_1<0,001; P_2<0,01	1,18±0,01 P_1<0,001
Leptin (ng/ml)	7,02±0,26	27,16±0,71 P_1<0,0000; P_2<0,0000	19,68±1,02
Ghrelin (pg/ml)	12,0±0,41	8,12±0,38 P_1<0,001; P_2<0,01	9,08±0,30
Peptide YY3-36 (pg/ml)	110,1±2,82	75,52±2,0 P_1<0,0001; P_2<0,001	86,01±2,60
Vitamin D (ng/ml)	27,13±1,23	19,41±0,74	23,11±0,52

Note: P_1 – compared to the control group; P_2 – differences

Based on the classification of the diagnosis of MS in children recommended by the IDF (2007), the level of indicators of the components of MS [20], the level of hyperglycemia and the presence of insulin resistance, triglyceridemia and a decrease in the level of HDL-C were assessed, and the state of blood pressure in children with abdominal obesity was also determined. The MS indicators in children with abdominal obesity were as follows: in 42.6% of cases, carbohydrate metabolism pathology was observed, in 52.9% of cases, lipid metabolism pathology, and in 25.0% of children, stage I and stage II of AH was observed.

Based on the obtained data, complete metabolic syndrome AO + 4 components was diagnosed in 13 children out of 68 children in the main sample (19.11%), AO + 3 components was diagnosed in 14 children (20.58%), AO + 2 components in 10 children (14.7%). The combination of AO with 1 component of MS was observed in 20 children (29.4%), the absence of signs of carbohydrate and lipid metabolism pathology in 11 (16.1%). Thus, a group of children with MS was formed, consisting of children with complete and incomplete MS - 37 children (54.4% of 68 children in the main sample) and a group without signs of MS or having 1 component of MS - 31 children (45.6%). It should be noted that in children with manifestations of metabolic syndrome, a state of vitamin D deficiency was observed in absolute numbers, which allows us to classify this indicator as one of the additional components of vitamin D in children.

Children with obesity presented various complaints (Table 2). The main complaint was increased appetite associated with a constant feeling of hunger. To assess the feeling of hunger, we used a 5-point scale for subjective assessment of the feeling of hunger developed by Bolotova N.V. et al. (2016) [13]. When applying this scale to children with different types of obesity, it was found that 37 children (54.4%) with abdominal obesity and 32 (53.3%) children with a generalized type complained of a constant feeling of hunger (5 points), i.e. a pronounced feeling of hunger was observed in both groups. In 21 children (30.1%) with AO, a strong feeling of hunger was suppressed by an abundant amount of food (4 points), 14 (23.3)% in the comparison group. A moderate feeling of hunger, which could be suppressed with a small amount of food, was observed in 10 (14.7%) children (3 points), 11 children (18.3%) in the comparison group, only 3 (5%) children had a moderate feeling of hunger corresponding to 2 points in children with GO.

Most children experienced headaches with increases in blood pressure. Stage I and II of arterial hypertension (from the 95th to the 99th percentile of blood pressure for the corresponding age, height and gender) was found in 17 (25.0%) children with abdominal obesity (4 children, 6.6% of children in the group with GO). High normal pressure was diagnosed with blood pressure from the 90th to the 95th percentile, with the same frequency in the group of children with AO 23 children (33.8%) and in the group of children with AO and 18 children (30.0%) with a generalized type of obesity.

Also, headache symptoms, episodes of stabbing pain in the heart area were encountered with high frequency, occurring both during physical exertion and at rest. Abdominal pain was noted, which was mainly observed in the epigastric zone and / or in the navel area and the right hypochondrium.

Table 2. Comparative characteristics of complaints in children with different types of obesity (n (%)

Complaints	I group (AO) n= 68	II group (GO) n= 60	Control group n= 40
Increased appetite	68 (100)*	57 (93,75)*	7 (21,8)
Hunger score 5 points	37 (54,4)*	32 (53,3)*	0
Hunger score 4 points	21 (30,1)*	14 (23,3)*	0
Hunger score 3 points	10 (14,7)	11 (18,3)	2 (6,25)
Hunger score 2 points	0	3 (5)	5 (15,6)
Headache	58 (85,2)*	46 (76,6)*	4 (10,0)
Heart pain	25 (36,7)*	15 (25,0)*	0
Pain in the epigastrium and abdomen	52 (76,4)*	41 (68,33)*	3 (7,5)
Dyspnea	59 (86,7)*	49 (81,6)*	0
Excessive sweating	65 (95,5)*	52 (86,6)*	3 (7,5)
Stretch marks	59 (86,7)*	50 (83,3)*	0
Hyperpigmentation	45 (66,1)*	40 (66,6)*	0
Increased BP			
Arterial hypertension 1-2 degrees	17(25,0)*,**	4(6,6)	0
High normal BP	23 (33,8)	18 (30,0)	2(6,25)

Note: ** - significance of difference with the control group - P<0.01; ** - significance of difference with the group with GO - P<0.01;*

The clinical symptom of "dyspnea" in children with AO and MS was present in most children of the compared groups, and occurred even with minor physical exertion. Complaints of children with different types of obesity can be seen in Table 2. Thus, the clinical picture of the disease, complaints did not differ in children with different types of obesity.

To evaluate the effectiveness and optimize the method of correction of the detected disorders, all children with abdominal obesity and generalized type of obesity were arbitrarily divided into three subgroups using the method of simple randomization. Subgroup Ia consisted of 22 children with AO who used ά-lipoic acid 200 mg 3 times a day for 1 month (in children under 14 years old, 100 mg 3 times a day), against the background of physiotherapy (TMT and TES). This category of children underwent motivational training in weight control, with a focus on maintaining a healthy lifestyle. Children and their parents were introduced to the principles of low-calorie nutrition and informed about the need for physical activity to increase energy expenditure.

Subgroup Ib included 22 patients with AO who, along with motivational training on weight loss, received vitamin D depending on the degree of obesity for 3 months, as well as TMT and TES.

In the Ic subgroup there were 24 children with AO, who, along with motivational training on weight loss, received a complex of ά-lipoic acid in the above dosage, vitamin D depending on the degree of obesity, as well as TMT and TES. It should be noted that all children with carbohydrate metabolism disorders were recommended metformin in a starting dose of 500 mg per day.

Group IIa consisted of 20 children with a generalized type of obesity who received ά-lipoic acid, TMT and TES and motivational training on weight loss, Group IIb also consisted of 20 children with RO who received vitamin D in a dosage depending on the degree of obesity, TMT and TES and motivational training on weight loss. Group IIc consisted of 20 children who received a complex of preparations from ά-lipoic acid, vitamin D and TMT and TES.

The effectiveness of therapeutic measures was assessed 3 months after the start of therapy.

First of all, we were interested in assessing the feeling of hunger, assessed at 5 points, the frequency of which, as in children of all subgroups with abdominal obesity, decreased, but statistically significantly in the group that received a combination of ά-lipoic acid, vitamin D and transcranial stimulation against the background of motivational training from 58.3% to 29.1% ($p<0.05$) (Table 3).

In all groups, a decrease in the frequency of assessing the feeling of hunger by 4 points was noted, but the difference did not have reliable values. It should be noted that an increase in the frequency of assessing the feeling of hunger by 3 points, and the appearance of a moderate feeling of hunger corresponding to 2 points was observed in children in group I of children with AO from 8.3% to 29.1% ($p < 0.01$) in the group of children who received combined therapy with ά-lipoic acid, transcranial physiotherapy and training in a weight loss school.

These facts characterize the applied method of combination therapy as a technique that has a suppressive effect on excited hunger centers in children with abdominal obesity, including those with MS components.

In groups of children who received a combination of ά-lipoic acid and transcranial stimulation, ά-lipoic acid and transcranial stimulation and vitamin D (Ia and IIc), a decrease in the frequency of complaints was observed, in particular headache, shortness of breath and increased sweating (Table 4).

Table 3. Comparative characteristics of clinical manifestations in various types of therapy in children with abdominal obesity (n (%)

Indicators	Group Ia n= 22		Group Ib n= 22		Group Ic n= 24	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Hunger score 5 points	12 (54,5)	8 (36,3)	11(50)	8 (36,3)	14(58,3)	7 (29,1) p<0,05
Hunger score 4 points	7 (31,8)	9 (30)	7 (31,8)	10 (5)	8 (33,3)	8 (33,3)
Hunger score 3 points	3(13,6)	5 (5)	4(18,1)	4	2(8,3)	7 (29,1) p<0,05
Headache	20 (91)	15 (68,1) p<0,05	18(81,8)	14 (63,6)	20 (83,3)	11(45,8) p<0,01
Dyspnea	19(86,3)	15 (68,1)	20(91)	15 (68,1) p<0,05	20(83,3)	10 (41,6) p<0,01
Excessive sweating	21(95,4)	16 (72,2) p<0,05	22(100)	16 (72,7) p<0,01	22(91,6)	10(41,6) p<0,01

Note: p - significance of difference compared to pre-treatment data

Table 4. Comparative characteristics of indicators in different types of therapy in children with abdominal obesity (M±m)

Indicators	Group Ia n= 22		Group Ib n= 22		Group Ic n= 24	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
BMI; M±m	32,12±0,68	31,16±0,34	33,59±0,45	32,12±0,58	33,14±0,33	31,12±0,61 p<0.005
SDS BMI	2,88±0,12	2,86±0,11	2,91±0,13	2,86±0,11	2,92±0,12	2,64±0,05 p<0.03
Fasting glucose (mmol/l)	5,06±0,05	4,90±0,03 p<0.008	5,10±0,04	4,89±0,03 p<0.000	5,14±0,01	4,91±0,03 p<0.000
Insulin (pmol/l)	60,15±1,69	58,16±1,1	62,21±1,51	59,11±1,15	64,22±1,23	59,54±1,18 p<0.008
Index IR HOMA $_R$ (standard units)	2,11±0,14	2,09±0,11	2,13±0,11	2,03±0,12	2,16±0,11	1,85±0,09
Triglycerides (mmol/l)	1,41±0,06	1,27±0,02 p<0.03	1,35±0,03	1,23±0,01 p<0.000	1,35±0,03	1,13±0,01 p<0.0000
Total cholesterol (mmol/l)	4,44±0,12	4,21±0,01	4,36±0,15	3,84±0,11 p<0.007	4,38±0,14	3,89±0,12 p<0.01
Leptin (ng/ml)	26,14±0,74	23,47±0,51 p<0.004	29,11±0,73	25,14±0,68 p<0.0002	29,69±0,76	23,11±0,65 p<0.0000
Ghrelin (pg/ml)	8,11±0,23	9,21±0,61	8,09±0,19	9,0±0,42	7,89±0,14	11,3±0,42
Peptide YY3-36 (pg/ml)	76,53±1,6	80,31±1.9	74,27±2,1	79,40±2,1	75,18±2,2	90,4±2,7 p<0.0000

Note: P - compared to baseline

When assessing the impact of various types of combination therapy on BMI, it was found that in children with AO, with a decrease in the average BMI and SDS BMI, no statistical differences were found in the subgroups, except for the method of combination therapy using ά-lipoic acid and transcranial physiotherapy and vitamin D (Tables 3 and 4).

In children of subgroup Ia, a positive therapeutic effect was observed in terms of reducing fasting glucose, triglycerides, and leptin levels. At the same time, with the combined use of vitamin D and TMT and TES in children with AO, a significant and reliable decrease in the level of fasting glucose, the level of immunoreactive insulin, triglycerides and total cholesterol was noted, but the IR HOMA R index after treatment, despite lower values compared to the initial confidence limits, did not have. In children of group Ic, a reliable improvement in all indicators of carbohydrate and lipid metabolism was observed. The level of hormones regulating appetite also had positive dynamics in children of group Ic (Table 4), which is associated with the effect of a running magnetic field and

electrical stimulation on the regulatory center of the hypothalamus responsible for eating behavior and perceiving signals of anorexigenic and orexigenic hormones.

It should be noted that in the group of children with GO, better therapeutic dynamics were observed when used in all subgroups, but with a better positive, reliable result with a combination of ά-lipoic acid, vitamin D and TMT and TES, expressed in a reliable decrease in body weight and an improvement in all metabolic and hormonal indicators (Tables 5, 6).

Table 5. Comparative characteristics of clinical manifestations in different types of therapy in children with a generalized type of obesity (n (%)

Indicators	Group IIa n= 20		Group IIb n= 20		Group IIc n= 20	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Hunger score 5 points	10(50)	6(30)	11(55)	6(30)	11(55)	4(20) p<0,02
Hunger score 4 points	5(25)	11(45) p<0,05	5(25)	5(25)	4(20)	4 (20)
Hunger score 3 points	4(20)	3 (25)	2(10)	7(20) p<0,05	5(20)	11(55) p<0,05
Hunger score 2 points	1		2(10)	2(15)	0	4(20) p<0,02
Headache	15 (75)	11(55)	15 (75)	9(45) p<0,05	16 (80)	10(50) p<0,05
Dyspnea	16(80)	10 (50) p<0,05	17(85)	12(60)	16 (80)	8(40) p<0,01
Excessive sweating	17(85)	10 (50) p<0,01	18 (90)	10(50) p<0,01	17(85)	7(35) p<0,01

Note: * - reliability of the difference compared to data before treatment

Table 6. Comparative characteristics of laboratory parameters in different types of therapy in children with generalized obesity (M±m)

Indicators	Group IIa n= 20		Group IIb n= 20		Group IIc n= 20	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
BMI; M±m	32,15±0,32	31,01±0,28 0.01	32,59±0,33	31,07±0,08 0.0000	33,01±0,34	31,86±0,18 0.004
SDS BMI	2,87±0,10	2,85±0,11	2,91±0,07	2,63±0,11 0.03	2,92±0,07	2,61±0,11 0.02
Fasting glucose (mmol/l)	4,89±0,02	4,85±0,01	4,98±0,02	4,73±0,03 0.0000	4,96±0,01	4,63±0,03 0,0000
Insulin (pmol/l)	50,11±2,12	45,12±1,12	48,22±1,81	42,11±1,05 0,000	51,03±1,16	43,15±1,22 0.0000
Index IR HOMA $_R$ (standard units	1,65±0,06	1,49±0,05 0.04	1,59±0,03	1,45±0,06*	1,61±0,03	1,44±0,05 0.005
Triglycerides (mmol/l)	1,14±0,02	1,05±0,01 0.001	1,16±0,02	1,04±0,02 0.000	1,15±0,03	1,03±0,01 0.000
Total cholesterol (mmol/l)	4,01±0,11	3,85±0,0	3,96±0,10	3,62±0,02 0.000	3,94±0,11	3,62±0,02 0.000
Leptin (ng/ml)	19,01±0,86	17,01±0,40 0.01	20,11±1,12	16,05±0,52 0.002	20,46±1,15	16,11±0,33 0.0007
Ghrelin (pg/ml)	9,01±0,21	10,82±0,40 0.0002	9,11±0,32	11,86±0,21 0.0000	9,08±0,27	11,89±0,28 0,0000
Peptide YY3-36 (pg/ml)	85,00±2,29	89,91±1,56	88,02±1,80	95,7±1,2 0.0000	87,01±1,62	96,6±1,5 0.0000

Note: P - compared to baseline

Thus, a positive effect was observed in the subgroups when using ά-lipoic acid and TMT and TES, vitamin D and TMT and TES in both observation groups, but with a better therapeutic effect in children with a generalized type of obesity. When using a combination of motivational training, ά-lipoic acid, vitamin D and TMT and TES, the therapeutic effect was the same in both children with abdominal obesity and children with a generalized type of obesity.

4. Conclusions

In children with abdominal obesity and generalized obesity, significant pathology of carbohydrate and lipid metabolism was observed, with more severe manifestations in children with visceral obesity.

Obesity in children is accompanied by a significant increase in basal leptin production, a decrease in fasting ghrelin secretion and peptide YY3-36, while the degree of pathology of these indicators depended on the type of obesity.

The frequency of MS in children with abdominal obesity was 54.5%, with AO+4 components diagnosed in 19.11%, AO+3 components diagnosed in 20.58%, and the frequency of incomplete MS in the form of AO+2 components diagnosed in 14.7% of children with abdominal obesity.

In children with obesity, statistically significant pathology of vitamin D metabolism was observed, characterized by cases of deficiency of 76.5% and cholecalciferol insufficiency of 46.7% in children with abdominal obesity compared to children with a generalized type of obesity.

Children with various types of obesity have significant disturbances in the nature of nutrition, accompanied by a strong, uncontrollable feeling of hunger with the consumption of a large volume of food.

The proposed combination treatment, including transcranial magnetic therapy and electrical stimulation against the background of motivational training on weight loss and the use of ά-lipoic acid, and differentiated prescription of vitamin D depending on the degree of obesity, contributed to a decrease in body weight in children with and was accompanied by correction of eating behavior, positive dynamics in the level of fasting glucose, insulin, blood, triglycerides, as well as anorexigenic and orexigenic hormones, regardless of the type of obesity.

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