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THE INFLUENCE OF MATERNAL OBESITY ON THE PHYSICAL DEVELOPMENT OFFSPRING IN THE FIRST YEAR OF LIFE

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Abstract. Obesity is a serious medical and social problem of modern health care system. The problem of maternal obesity associated with gynaecological, perinatal risks and risk of developing diseases in offspring. It has been proven that excess body weight before pregnancy is a significant risk factor for the development of obesity and metabolic syndrome in children. The article presents data from an analysis of physical development in children in the first year of life born to obese mothers.

Keywords: *physical development, children, maternal obesity, excess body weight*

ВЛИЯНИЕ МАТЕРИНСКОГО ОЖИРЕНИЯ НА ФИЗИЧЕСКОЕ РАЗВИТИЕ ПОТОМСТВА В ПЕРВЫЙ ГОД ЖИЗНИ

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Резюме. Ожирение является серьезной медико-социальной проблемой современного здравоохранения и достигает в мире масштабов эпидемии. Проблема материнского ожирения связана как с акушерско-гинекологическими и перинатальными рисками, так и с долгосрочным влиянием материнского ожирения на состояние здоровья потомства. Доказано, что избыточная масса тела до беременности является существенным фактором риска развития ожирения и метаболического синдрома у детей. В статье представлены данные анализа физического развития у детей, в первый год жизни, рожденных от матерей с ожирением.

Ключевые слова: *физическое развитие, дети, материнское ожирение, избыточная масса тела*

INTRODUCTION

Obesity is a serious medical and social problem of modern public health. It is reaching epidemic proportions worldwide. According to the World Health Organization (WHO) report on obesity in Europe for 2022, about 55.5% of the adult population is overweight and obese [1]. The incidence of obesity among women of childbearing age is also

steadily increasing [1]. This trend is currently the most alarming, as numerous studies have proven the role of maternal obesity in the development of complications of pregnancy and childbirth, such as habitual miscarriage, preeclampsia, gestational diabetes mellitus, gestational arterial hypertension, weak labor, increased incidence of operative delivery, bleeding in labor and early postpartum, traumatic injuries in the mother and fetus, infections in the area of surgical interventions, and intrauterine retention [2–4]. Besides complications of pregnancy, childbirth and perinatal risks, the long-term effects of maternal obesity are actively studied. It has been proved that excessive body weight before pregnancy is a significant risk factor for the development of obesity and metabolic syndrome in offspring [5, 6]. Analysis of 2416 population studies revealed that from 1975 to 2016, there was an increasing trend in BMI in children and adolescents [7]. Childhood obesity, in turn, is associated with the risk of developing diseases in adulthood, such as metabolic syndrome, cardiovascular and musculoskeletal diseases, atopic dermatitis, type 2 diabetes mellitus, and the development of psychological problems [8–11].

AIM

To analyze the dynamics of physical development in children in the first year of life born to obese mothers.

MATERIALS AND METHODS

90 children were included in the study: Group 1 — 54 children from obese mothers (mother's body mass index (BMI) before pregnancy ≥30 kg/m^2; Group 2 — 36 children from mothers with normal BMI (18.5–24.9 kg/m2). The mean maternal BMI at the time of delivery in group 1 was 38.1 kg/m^2 and in group 2 was 22.7 kg/m^2. The number of children born through natural labor was 66.1%, and by cesarean section — 33.9%. The number of premature neonates in the groups was 4.6%, and 95.4% neonates were full-term. The average gestational age of newborns was 39 weeks in both groups. Girls accounted for 46.8%, boys — 53.2% in the studied groups.

Anthropometric parameters were assessed at birth according to sex and gestational age using INTERGROWTH-21st standards [12]. The INTERGROWTH-21 scale (size at birth charts) was developed on the basis of data obtained by measuring weight, body length, and head circumference in healthy newborns of different gestational ages (33–42 weeks). Parameters within ±1 SD were evaluated as a variant of mean values. Deviations which were more or less than 1 SD from the median were evaluated as "above average" and "below average", respectively.

All children were assessed for anthropometric parameters every month. These parameters were further analyzed by sex and age according to WHO standards for children by means of the WHO Anthro program. Anthropometric parameters were assessed in standard deviations from the mean (SDS — standard deviation score). Parameters within ±1 SD were evaluated as a variant of mean values. Deviations which were more or less than 1 SD from the median were evaluated as "above average" and "below average", respectively. Body mass index (BMI), which is calculated as the ratio of body weight in kilograms (kg) to the square of body length expressed in meters (m^2), is the most informative method since it is difficult to determine the amount of body fat directly. BMI has been shown to correlate with the amount of body fat in both adults and children. BMI was calculated according to the standards for a particular age and sex and was presented as the number of standard deviations from the mean (SDS).

Statistical processing of the material was carried out using standard methods of mathematical statistics and IBM SPSS Statistics 26 software package. Description of quantitative data was presented in the form of sample mean standard deviation and 95% confidence interval in the form of M±σ (95% CI) in case hypothesis of normal distribution is accepted. If this hypothesis was rejected, median (Me) and quartiles of Q1 and Q3 were presented in the format Me (Q1; Q3). The Shapiro–Wilk and Kolmogorov–Smirnov criteria were used to test the hypothesis of normal distribution. The Student's criterion (with Welch's correction if there were different dispersions) was used to compare independent samples. Absolute value and relative value in percentage were specified for qualitative indicators. Qualitative attributes of the groups were compared using Pearson's χ^2 criterion. The results were considered statistically significant at the $p < 0.05$ level.

RESULTS

The research analyzed the dynamics of somatometric indicators and harmony of physical development in children born to obese mothers compared to children born to mothers with nor-

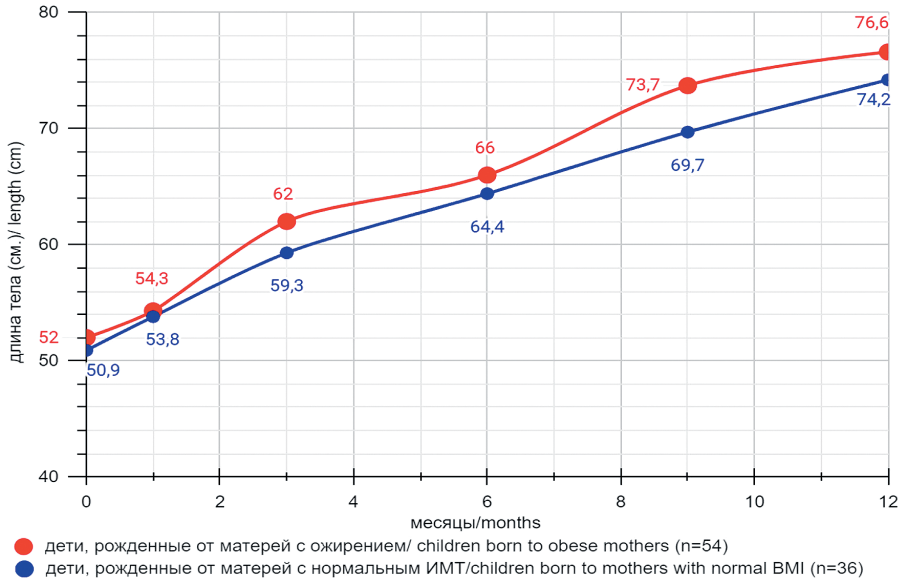

Fig. 1. Dynamics of body length in groups of children born to obese women and women with normal body mass index (BMI) (hereinafter in figure captions)

Рис. 1. Динамика длины тела в группах детей, рожденных женщинами с ожирением и женщинами с нормальным индексом массы тела (ИМТ) (здесь и далее в подрисуночных подписях)

Table 1. Increases in body length (cm) in examined children in 2 groups during the observation period

Таблица 1. Прибавки длины тела (см) у обследованных детей в 2 группах за период наблюдения

Прибавки длины тела в группах (см) / Increases in body length in groups (cm)	Период, месяцы / Period, months				
	0–1	1–3	3–6	6–9	9–12
Дети от матерей с ожирением / Children of obese mothers	2,3±0,2	7,7±0,4	4,0±0,2	7,5±02	2,9±0,1
Дети от матерей с нормальным ИМТ / Children from mothers with normal BMI	2,9±0,4	5,2±0,4	5,1±0,1	5,2±0,3	4,9±0,2
Примечание / Note	p=0,42	p=0,001	p=0,04	p=0,002	p=0,001

mal BMI. The dynamics of average body length is presented in Fig. 1.

Newborns born to obese mothers had statistically significantly higher body length indices than newborns born to mothers with normal BMI (p=0.009). At one month of age, the average body length was almost similar in both groups (p=0.184). However, subsequent decremental check-ups showed that the comparison group had higher body length indices than the controls at 3 months (p <0.001), 6 months (p=0.001), 9 months (p <0.001) and 12 months (p <0.001). This was attributed to higher body length gains at 1–3 and 6–9 months. The data are summarized in Table 1.

The level of physical development in children during the first year of life was assessed by comparing body length with WHO age-specific standards (Child Growth Standards, 2006). The Z-score for body length was calculated for each child. Depending on the individual Z-score value, children were divided into the following groups:

- average physical development (APD) — Z-score between +1 and –1;
- below average physical development (BAPD) — Z-score in the range from 1.1 to 2.0;
- low physical development (LPD) — Z-score ≤–2.1;
- above average physical development (AAPD) — Z-score in the range from +1.1 to +2;
- high physical development (HPD) — Z-score ≥+2.
- The distribution of children in both groups by level of physical development is shown in Fig. 2.

Average physical development in newborns in both groups was recorded with the same frequency (29.6 and 19.4%, p=0.1). Frequency of other variants of physical development showed

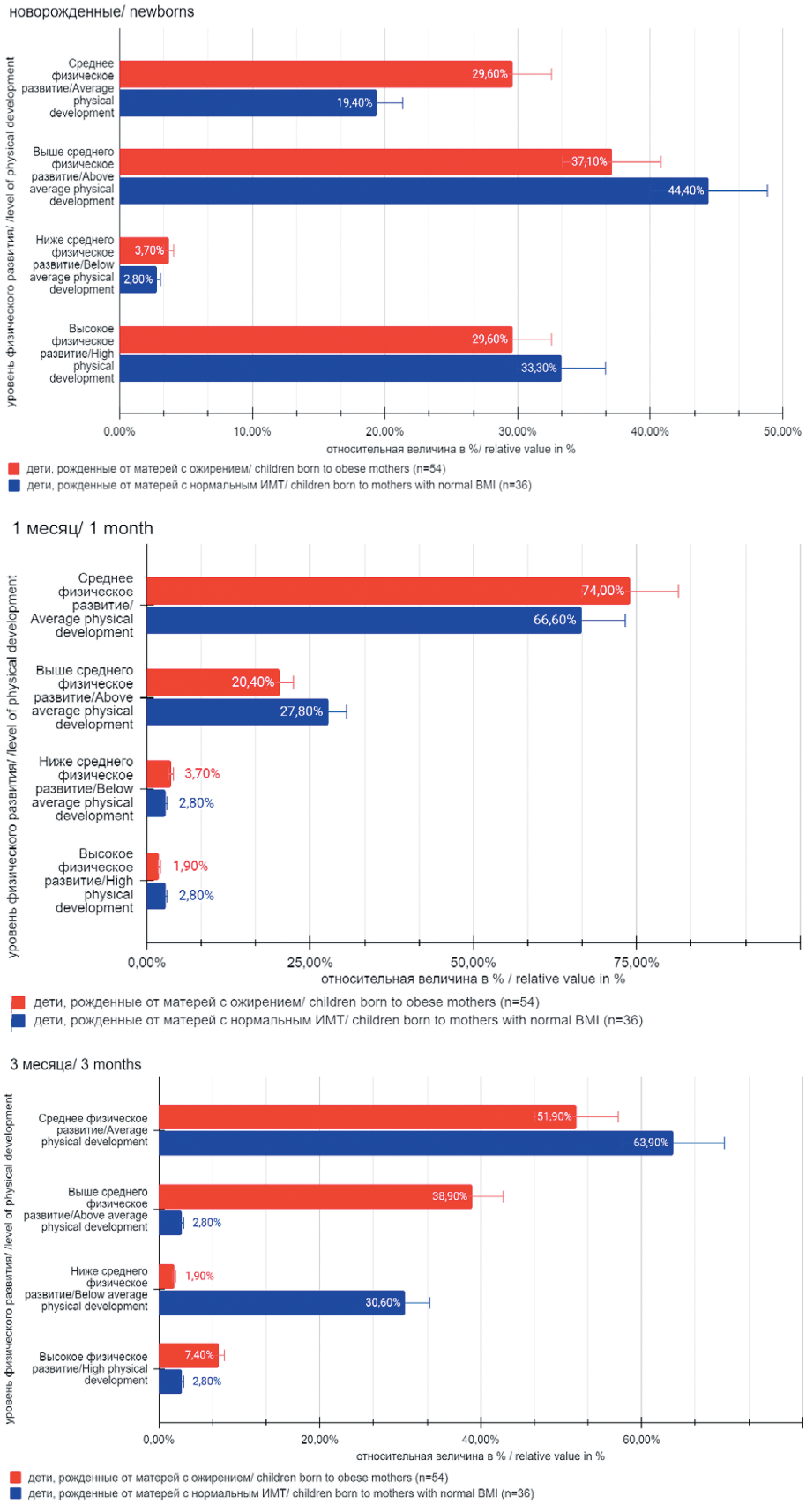

Fig. 2. Distribution of children by level of physical development, in groups of children born to obese mothers and mothers with normal BMI

Рис. 2. Распределение детей по уровню физического развития в группах детей, рожденных от матерей с ожирением и матерей с нормальным ИМТ

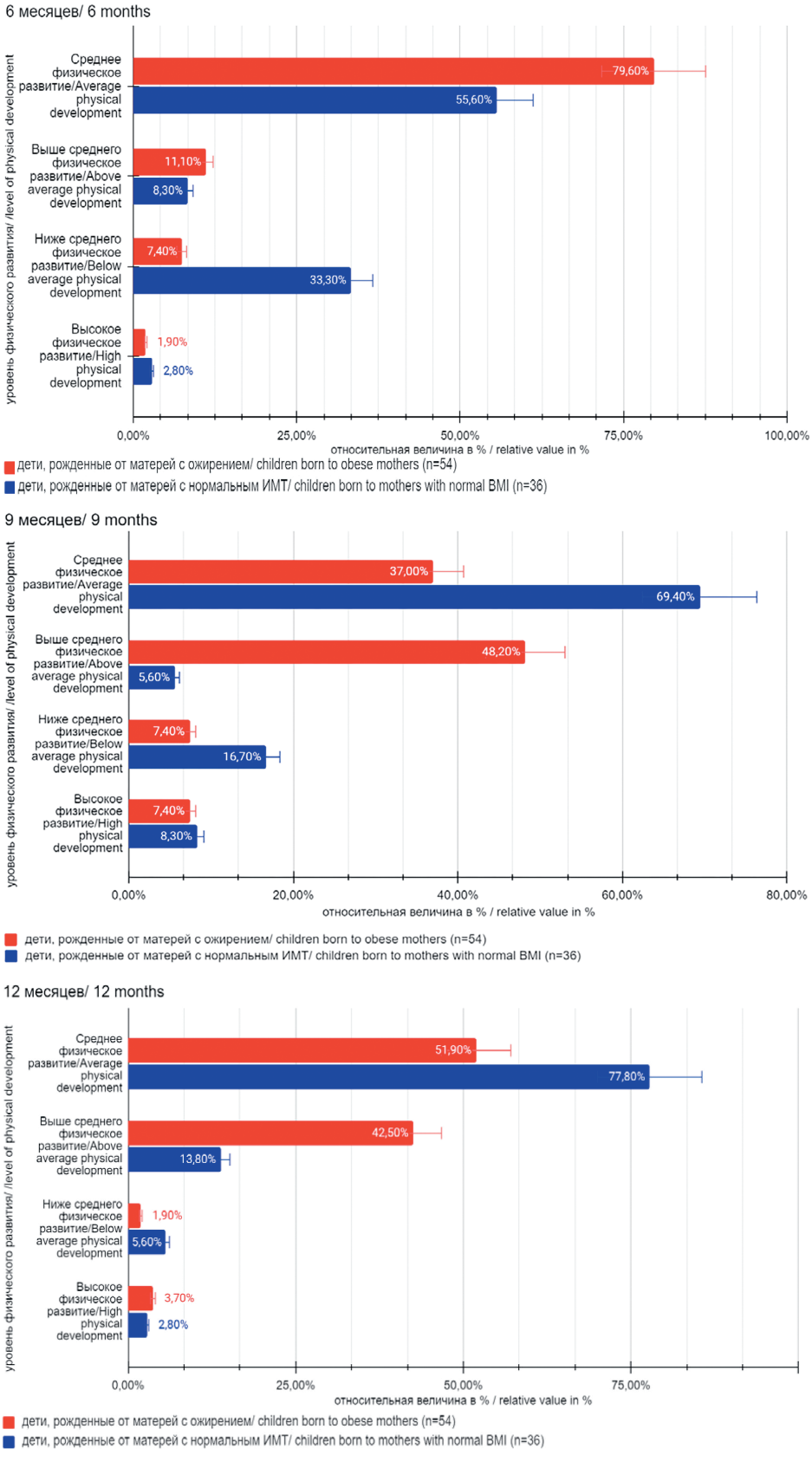

Fig. 2. *Continuation*. Distribution of children by level of physical development, in groups of children born to obese mothers and mothers with normal BMI

Рис. 2. *Продолжение*. Распределение детей по уровню физического развития в группах детей, рожденных от матерей с ожирением и матерей с нормальным ИМТ

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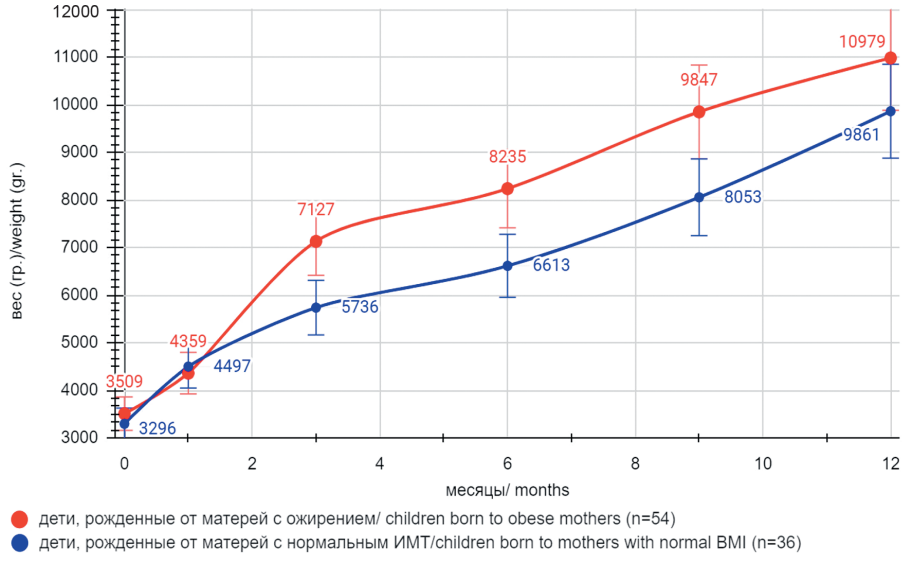

Fig. 3. Dynamics of body weight in children born to obese mothers and children born to mothers with normal BMI

Рис. 3. Динамика массы тела у детей, рожденных от матерей с ожирением, и детей, рожденных от матерей с нормальным ИМТ

no statistically significant difference. However, newborns in Group 1 were more likely to have below average physical development (3.7 and 2.8%) compared to those in Group 2.

At one month of age, all variants of physical development were registered with the same frequency in the studied groups: APD (74.0 and 66.6%, p=0.4), BAPD (3.7 and 2.8%, p=0.3), AAPD (20.4 and 27.8%, p=0.4) and HPD (1.9 and 2.8%, p=0.3).

At 3 months of age, children born to obese mothers were statistically more likely to have AAPD (38.9 and 2.8%, p=0.002) compared to controls. Children born to women with normal BMI were more often diagnosed with average physical development (51.9 and 63.9%, p=0.08) and below average physical development (1.9 and 30.6%, p=0.004). High physical development appeared with equal frequency in the two groups (7.4 and 2.8%, p=0.3).

At 6 months of age, children born to obese women were more likely to have average physical development (79.6 and 55.6%, p=0.04) than the comparison group. AAPD (11.1 and 8.3%, p=0.08) and HPD (1.9 and 2.8%, p=0.2) had no statistically significant differences in both groups. Below average physical development was statistically significantly more common in children born to women with normal BMI (7.4 and 33.3%, p=0.03).

At 9 months, average physical development was more frequently recorded in children born to women with normal BMI (37.0 and 69.4%, p=0.03), while children born to obese women were more frequently diagnosed with AAPD (48.2 and 5.6%, p=0.002). High physical development (7.4 and 8.3%, p=0.1) and below average physical development (7.4 and 16.7%, p=0.4) were diagnosed with equal frequency in both groups.

At 12 months, above average physical development was more often registered in Group 1 (42.5 and 13.8%, p=0.004). Average physical development (51.9 and 77.8%, p=0.04) was statistically significantly more often registered in Group 2. Below average physical development (1.9 and 5.6%, p=0.3) and high physical development (3.7 and 2.8%, p=0.4) had no statistically significant differences in the groups.

The average values of body weight indices in the group of neonates born to obese mothers were also higher than in neonates born to mothers with normal BMI (p=0.004). At the age of one month, body weight indices in both groups had no differences (p=0.150). However, starting from 3 months of life, the body weight indices of children in the first group were higher than in the second group (p <0.001). The data are presented in Fig. 3.

Children born to obese women had more significant weight gain in the period from 1 to 9 months. However, in the period from 9 to 12 months, statistically significant weight gain was higher in children from women with normal BMI. The data are summarized in Table 2.

Absolute body weight values were assessed according to the individualized Z-score. Individual Z-score weight values between +1 and –1 were taken as average body weight values. Undernu-

Table 2. Rates of weight gain (g) in children born to obese mothers and mothers with normal BMI during the observation period

Таблица 2. Темпы прибавки массы тела (г) у детей, рожденных от матерей с ожирением и матерей с нормальным ИМТ, за период наблюдения

Прибавки массы тела в группах (г) / Body weight gain in groups (g)	Период, месяцы / Period, months				
	0–1	1–3	3–6	6–9	9–12
Дети от матерей с ожирением / Children of obese mothers	850±55	2768±16	1108±12	1612±40	1132±135
Дети от матерей с нормальным ИМТ / Children from mothers with normal BMI	1097±102	1239±86	877±43	1440±151	1808±34
Примечание / Note	p=0,2	p=0,001	p=0,04	p=0,06	p=0,02

trition (UN) was diagnosed when body weight Z-score was between –1.1 and –2. Malnutrition (MN) was diagnosed with body weight Z-score ≤–2.1. A child was considered to be overweight (OW) if body weight Z-score was ≥+1.1. Children with Me ≥+2SD were analyzed separately. The distribution of body weight values in both groups is shown in Fig. 4.

The predominant number of newborns had average absolute body weight values by the moment of birth (55.6% in Group 1, and 55.6% in Group 2) p=0.5). Underweight (5.6 and 8.3%, p=0.2) and overweight (3.7 and 8.3%, p=0.1) had no statistically significant differences in both groups at birth . This trend was maintained until 3 months of age.

At 3 months, average body weight values were more often registered in the group of children born to women with stable normal BMI (44.4 and 77.8%, p=0.02), while children born to obese mothers were statistically significantly more often diagnosed as overweight (40.8 and 5.6%, p=0.02). Children in this group were also more likely to have body weight values ≥+2SD (7.4 and 2.8%, p=0.04). Undernutrition (3.7 and 11.1%, p=0.04) was more frequently recorded in children from women with normal BMI. Malnutrition was equally registered in both groups (p=0.1).

At 6 months, average body mass indices were more frequently registered in Group 1 (70.4 and 44.4%, p=0.02). Overweight was also more frequently diagnosed in children of the 1st group (25.9 and 11.2%, p=0.04), while undernutrition (0.0 and 22.2%, p=0.02) and malnutrition (0.0 and 16.7%, p=0.02) were statistically more frequently registered in the 2nd group.

At 9 months, average body weight indices had no statistically significant differences in both groups (37.0 and 50.0%, p=0.1). Undernutrition (1.9 and 22.2%, p=0.03) was more frequently recorded in the group of children from women with normal BMI, and overweight was more frequently diagnosed in the group of children from obese women (48.1 and 11.2%, p=0.02).

At 12 months, overweight was more frequently diagnosed in Group 1 (50.0 and 25.0%, p=0.01). Children in Group 1 were statistically more likely to have body mass indexes above ≥+2SD (14.8 and 8.3%, p=0.04). Undernutrition was more frequently recorded in Group 2 (1.9 and 11.2%, p=0.03). Average body weight (29.6 and 47.2%, p=0.1) and malnutrition (3.7 and 8.3%, p=0.4) were equally registered in both groups.

The harmony of physical development was assessed by Kettle's mass and height index 2. Its value was determined by dividing body weight (kg) by the square of body length (m2). The following variants of physical development were distinguished depending on BMI: harmonious physical development (HFD), Z-score +1 to –1; disharmonious physical development due to body mass deficiency (BMD), Z-score –1.1 to –2; malnutrition (MN), Z-score BMI ≤–2.1; overweight (OW), Z-score +1.1 to +2. Children with Me ≥+2SD were analyzed separately. A comparative analysis of distribution in both groups according to harmony of body length/weight ratio is presented in Fig. 5.

At birth, harmonious physical development was registered in the predominant majority of newborns in both groups and had no statistically significant differences (74.1 and 61.1%, p=0.2). Disharmonious physical development due to overweight (3.7 and 8.3%, p=0.3), underweight (14.8 and 19.5%, p=0.09) and malnutrition (3.7 and 8.3%, p=0.3) was diagnosed with equal frequency in both groups.

During the first month, harmonious physical development was also observed in the majority of infants in both groups (46.3% and 55.5%, p=0.3). However, children born to obese mothers were

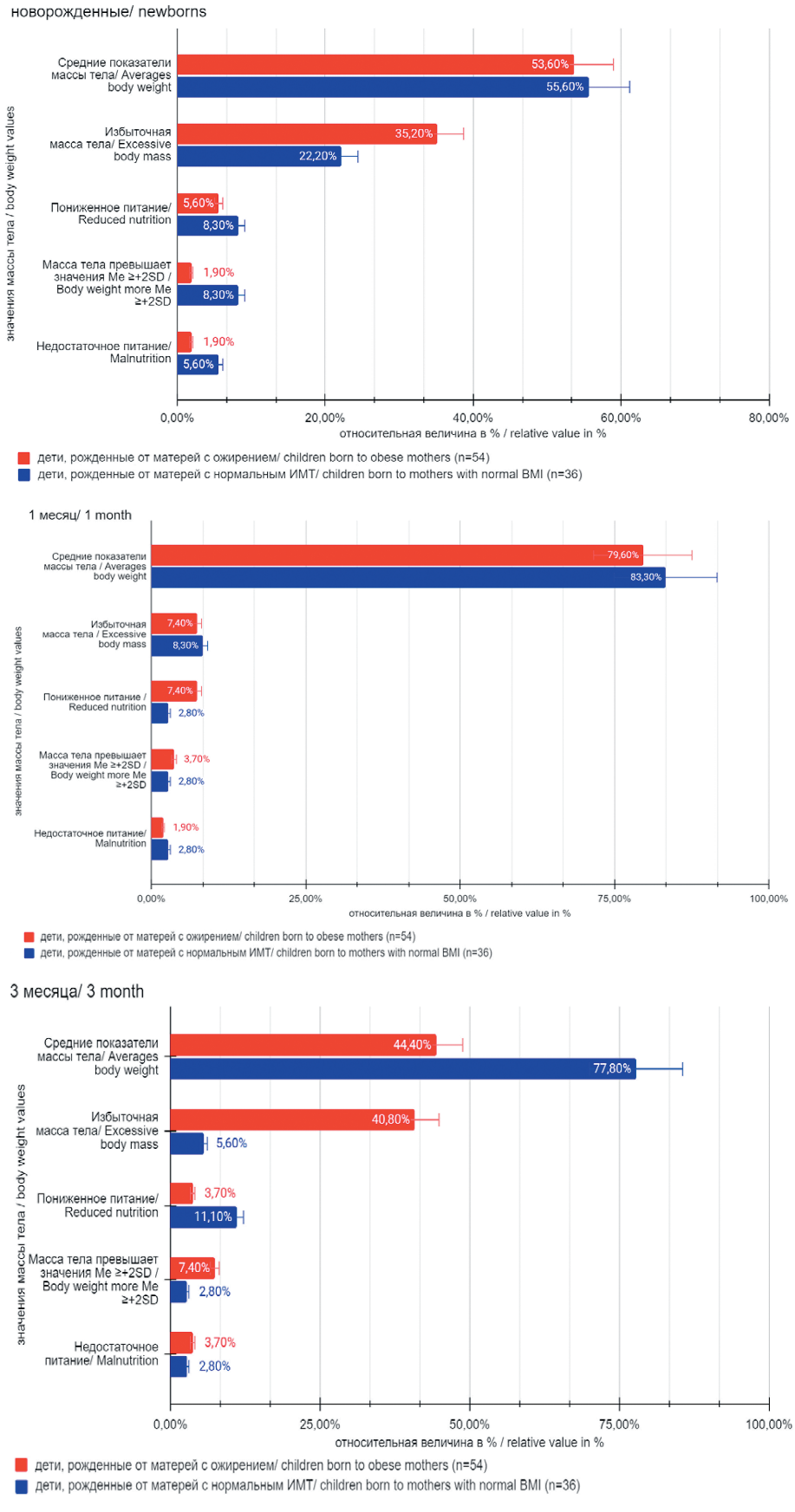

Fig. 4. Distribution of children by body weight, in groups of children from obese women and women with normal BMI

Рис. 4. Распределение детей по массе тела в группах детей от женщин с ожирением и женщин с нормальным ИМТ

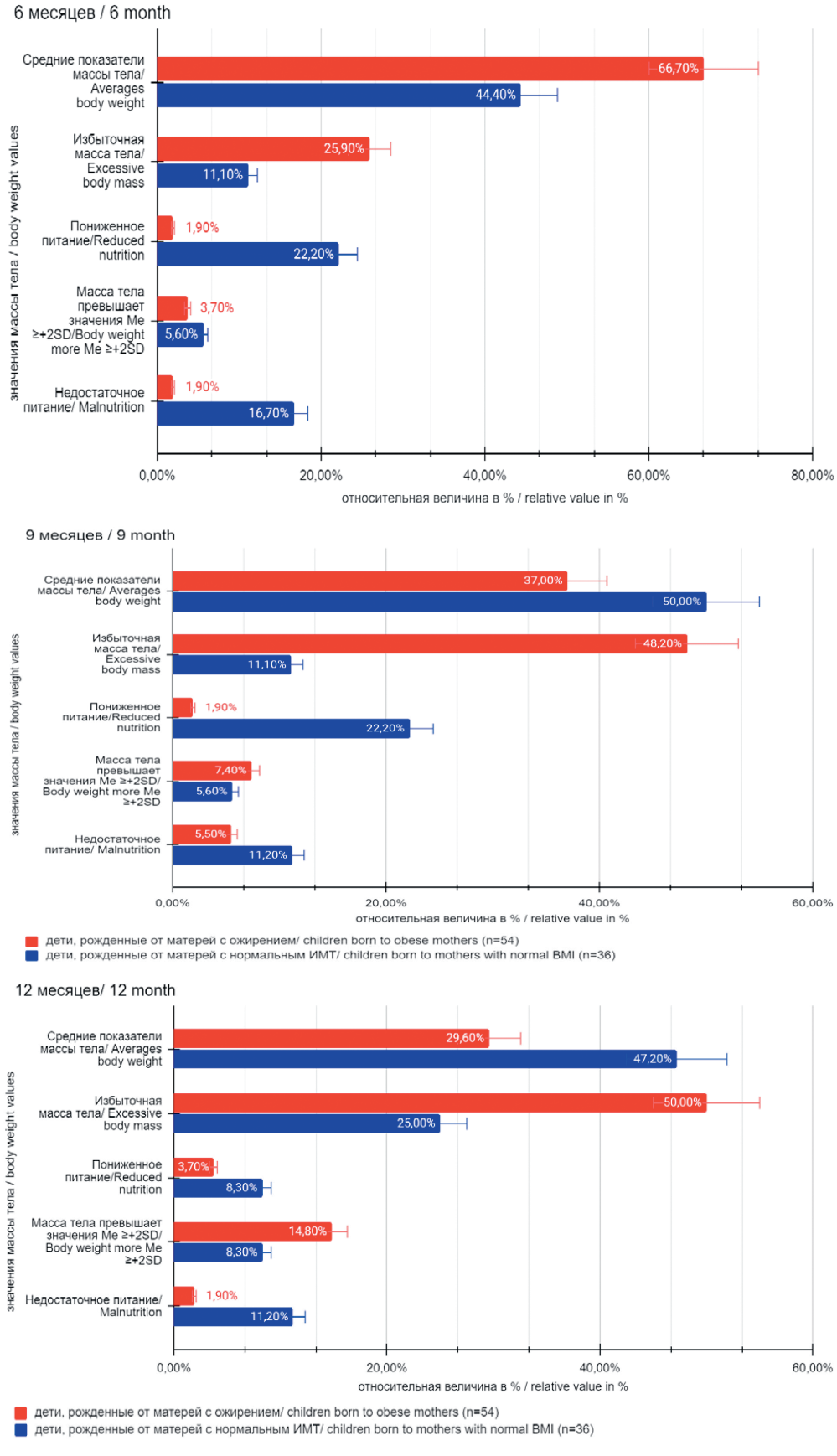

Fig. 4. *Continuation.* Distribution of children by body weight, in groups of children from obese women and women with normal BMI

Рис. 4. *Продолжение.* Распределение детей по массе тела в группах детей от женщин с ожирением и женщин с нормальным ИМТ

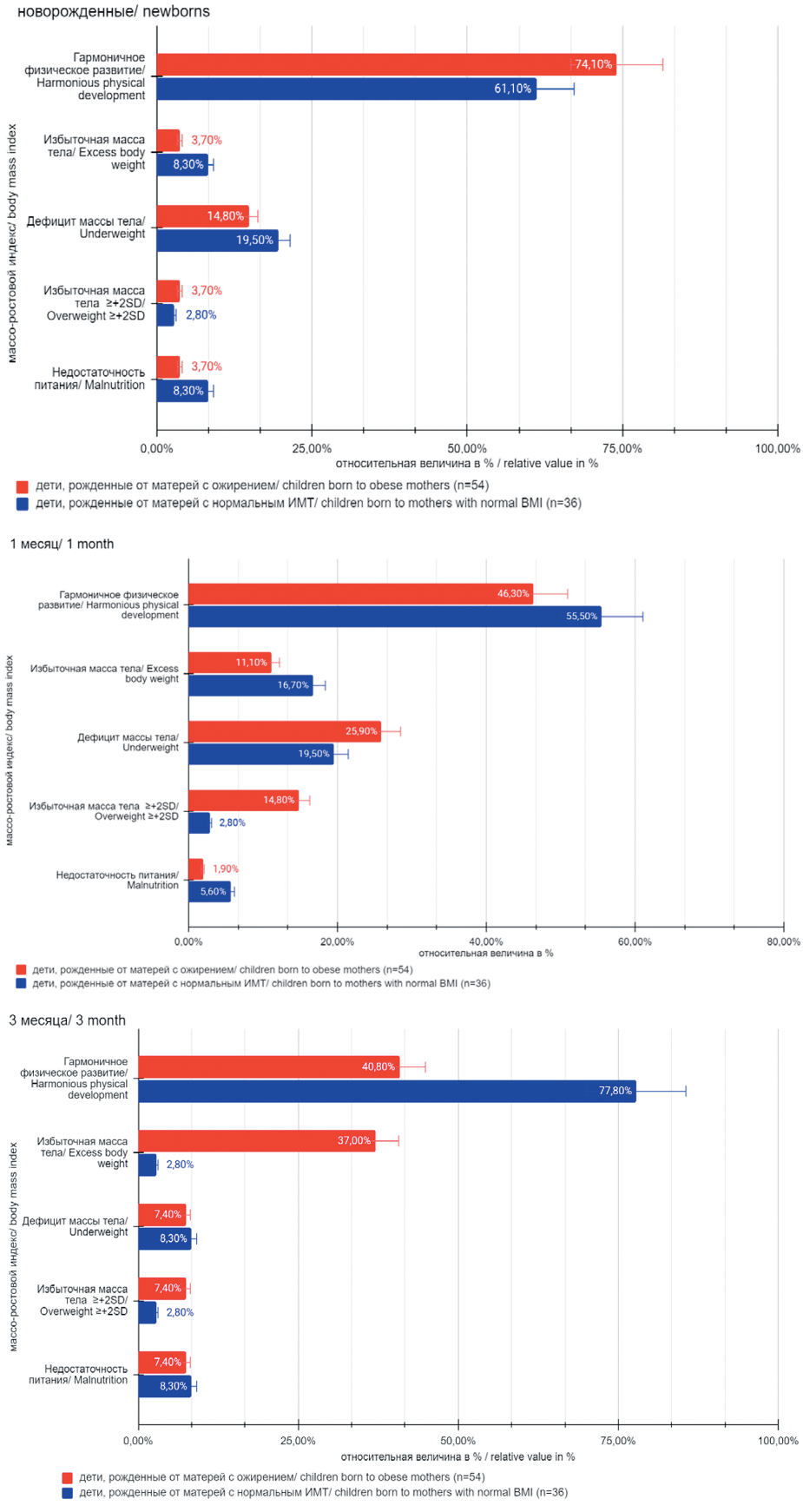

Fig. 5. Distribution of children by body mass index (BMI) in groups of children from obese mothers and mothers with normal BMI

Рис. 5. Распределение детей по массо-ростовому индексу (ИМТ) в группах детей от матерей с ожирением и матерей с нормальным ИМТ

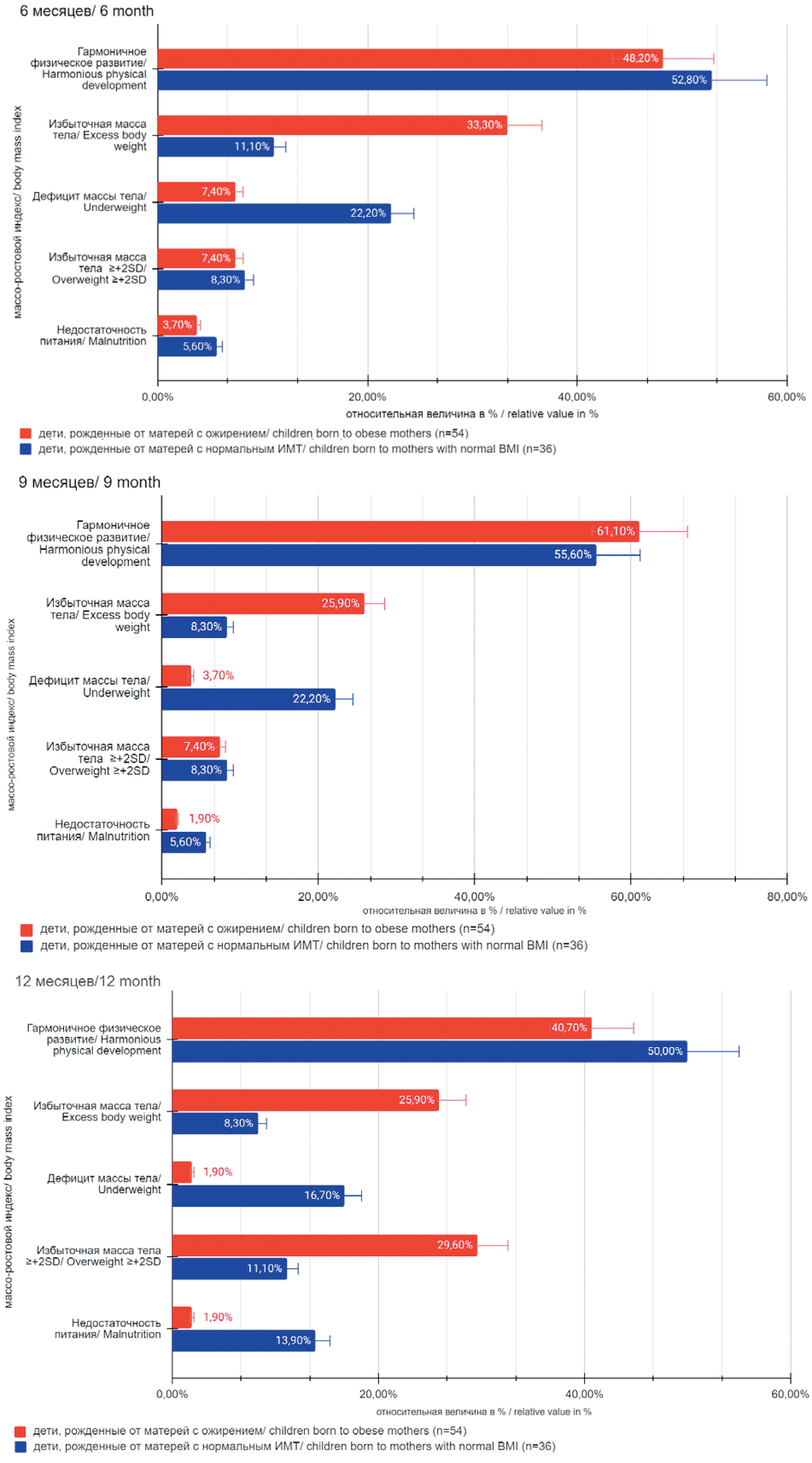

Fig. 5. *Continuation*. Distribution of children by body mass index (BMI) in groups of children from obese mothers and mothers with normal BMI

Рис. 5. *Продолжение*. Распределение детей по массо-ростовому индексу (ИМТ) в группах детей от матерей с ожирением и матерей с нормальным ИМТ

statistically more often diagnosed with excessive body weight exceeding Me ≥+2SD (14.8 and 2.8%, p=0.04). The frequency of disharmonious physical development due to body weight deficiency (25.9 and 19.5%, p=0.1) and malnutrition (0.0 and 5.6%, p=0.3) had no statistically significant differences in the studied groups.

At 3 months, children in Group 2 were statistically significantly more likely to have harmonious physical development (40.8 and 77.8%, p=0.03), while children in Group 1 were statistically more likely to demonstrate disharmonious physical development due to excess body weight (37.0 and 2.8%, p=0.02). However, excessive body weight which exceeded Me ≥+2SD occurred equally often in both groups (7.4 and 2.8%, p=0.3). Disharmonious physical development due to body weight deficiency (7.4 and 22.2%, p=0.04) and malnutrition (7.4 and 8.3%, p=0.1) was recorded with equal frequency in both groups.

At 6 months, harmonious physical development prevailed in all groups (48.2 and 52.8%, p=0.4). Disharmonious physical development due to excessive body weight (33.3 and 11.1%, p=0.03) was registered more often in children born to obese women. However, there were no statistically significant differences in the disharmonious physical development due to BMI exceeding Me ≥+2SD (7.4 and 8.3%, p=0.1). Children born to women with normal BMI were more frequently diagnosed with disharmonious physical development due to weight deficit (7.4 and 22.2%, p=0.04). Malnutrition (3.7 and 5.6%, p=0.1) was diagnosed with equal frequency in the groups.

At 9 months, the majority of children in both groups had a body weight to body length ratio (BWLR) of 61.1 and 55.6% (p=0.2). Group 1 showed a predominance of disharmonious variants of physical development caused by excessive body weight (25.9 and 8.3%, p=0.04), while controls demonstrated disharmonious physical development due to weight deficit (3.7 and 22.2%, p=0.02). Overweight exceeding Me ≥+2SD (7.4 and 9.3%, p=0.1) and malnutrition (1.9 and 8.3%, p=0.07) occurred with equal frequency in both groups.

At 12 months, harmonious physical development prevailed in both groups as well (40.7 and 50.0%, p=0.2). Children born to obese women more often had disharmonious physical development due to excessive body weight (25.9 and 8.3%, p=0.04), including those exceeding Me ≥+2SD (29.6 and 11.1%, p=0.03). In contrast, children born to women with normal BMI were more often diagnosed with disharmonious physical development due to weight deficit (29.6 and 11.1%, p=0.03). Malnutrition was diagnosed with the same frequency (1.9 and 13.9, p=0.06).

There was also conducted a correlation analysis of the dynamics of body length, body weight and weight-growth index of children depending on the mother's BMI. Correlation analysis revealed a positive correlation of maternal BMI with offspring body weight at birth, length and body weight of children at the age of 3, 6, 9 and 12 months, as well as a positive correlation of maternal BMI with the weight-growth index of children at the age of 6 and 12 months. The data are presented in Table 3.

The obtained results demonstrate that children born to obese mothers have higher integral indices of physical development at birth. It is worth noting that there is a tendency to accelerate the rate of weight and body length gain starting from 3 months of life in Group 1. Thus, this group demonstrates statistically significant differences

Table 3. Correlation of maternal BMI with indicators of physical development in children in both groups

Таблица 3. Корреляция материнского ИМТ с показателями физического развития у детей в обеих группах

Показатель / Index	Новорожденные / Newborns	1 месяц / 1 month	3 месяца / 3 month	6 месяцев / 6 month	9 месяцев / 9 month	12 месяцев / 12 month
Длина тела / length	r=0,043 p=0,799	r=–0,171 p=0,305	r=0,650** p<0,01	r=0,453* p=0,004	r=0,751** p<0,01	r=0,375* p=0,02
Масса тела / Body mass	r=0,772** p <0,01	r=–0,088 p=0,6	r=0,562** p <0,01	r=0,592** p <0,01	r=0,505** p=0,001	r=0,350* p=0,03
Массо-ростовой индекс/ Body mass index	r=0,170 p=0,308	r=-0,153 p=0,361	r=0,285 p=0,083	r=0,537** p=0,001	r=0,039 p=0,817	r=0,456* p=0,02

**Корреляция значима на уровне 0,01 (двухсторонняя) / Correlation is significant at the 0.01 level (2-tailed).

*Корреляция значима на уровне 0,05 (двухсторонняя)/ Correlation is significant at the 0.05 level (2-tailed).

in disharmony of physical development at the age of 12 months, mainly due to excessive body weight.

CONCLUSION

The obtained results of physical development analysis prove the influence of maternal obesity on anthropometric indicators in offspring and indicate the risks of obesity and metabolic syndrome formation at an early age. Children with excess body weight at 12 months are at risk of developing obesity at school age. Childhood obesity is associated with metabolic disorders — diseases of the cardiovascular system, gastrointestinal tract, and musculoskeletal system in adulthood. The topic requires further study to identify possible mechanisms of maternal obesity influence on the physical development and health of offspring as well as to identify simple, accurate markers of metabolic disorders associated with obesity in young children.

ADDITIONAL INFORMATION

Author contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

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Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией.

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