The Relation Between Prenatal Stress, Overweight and Obesity in Children Diagnosed According to BMI and Percentage Fat Tissue.

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Abstract

Background

Overweight and obesity in children have a negative impact not only on the physical development but also on the mental health of children. That is why researchers are constantly looking for possible causes of such high frequency of this phenomenon. One of the environmental factors contributing to abnormal weight changes in children may be maternal exposure to adverse environmental factors during pregnancy, which in previous studies led to inconclusive results showing both overweight and obesity and underweight in children. The aim of the study was to examine the relationship between prenatal stress and body weight status.

Methods

The cohort study included 254 girls and 276 boys. Information on prenatal stress was collected with a questionnaire completed by a parent/guardian of a 6–12-year-old child. We assessed the body mass status on the basis of BMI according to the IOTF criterion and on the basis of body fat according to McCarthy criterion.

Results

The results of our study show that the prenatal stress was related to increased risk of overweight (OR 2.14, 95%CI: 1.25-3.65) diagnosed on the basis of body fat cut-off points, but not when the BMI was a diagnostic criterion (OR 1.03, 95%CI:0.58-1.83).

Conclusion

The method of diagnosis based on the fat content appears to be an indicator of the occurrence of abnormalities in body composition due to prenatal stress more sensitive than that based on the BMI.

Level of evidence: Evidence obtained from well-designed cohort or case-control analytic studies

1. Purpose

Excessive body weight in children adversely affects their development and health. It is associated with the risk of developing type I [1, 2] and II diabetes [3], but also leads to an increase in total cholesterol [4, 5], triglycerides [5] and blood pressure [4–6], increases the risk of atherosclerosis [7], non-alcoholic fatty liver disease [8] and metabolic syndrome [9]. Excessive body weight is also frequent comorbidity of the mental health problems such as depression [10, 11] and ADHD [12]. It is known that factors like too high energy supply, too little physical activity, a diet rich in simple sugars and saturated fatty acids increase the risk of overweight and obesity in children [13]. The results of some studies indicate that nutritional awareness is not significantly related to BMI, which means that the knowledge of the principles of proper nutrition is not sufficient in the effective prevention of overweight and obesity [14, 15]. The very knowledge of nutrition does not limit the scale of the phenomenon. It is quite the opposite; the trend is increasing. The prevalence of overweight and obesity in the world was 4% in 1975 and in 2016 the excessive weight was found to be 18% [16]. Thus, it is crucial for further studies to search the causes and factors modifying the development of overweight and obesity.

Previous research shows that not only postnatal life, but also the environment in intrauterine life affects the child's body weight [17, 18]. Adverse factors experienced by the mother during pregnancy may have a programming effect on the fetal metabolism, and affect changes in the body weight and proportions in the later life [19]. Prenatal stress deserves special attention in the context of obesity research. Previous research has shown that stressors such as parting with biological father during pregnancy [20] or difficulties caused by a snowstorm may be related to obesity [21, 22]. If prenatal stress is an important risk factor, preventive and therapeutic interventions to reduce stress during pregnancy could actually reduce the risk of obesity and its health complications in the offspring. Nevertheless, the results of previous studies are inconclusive and there are also studies that did not confirm the relationship [23, 24]. Thus, the problem requires further research.

The most commonly studied anthropometric indicator of excessive weight among children is Body Mass Index (BMI), which is used on a large scale because the examination is easy, fast, and requires no specialized equipment. However, BMI is not an ideal fatness indicator [25, 26]. While assessing body weight based on BMI, it is possible to overestimate the risk of excessive body weight in children who have high lean body mass [27, 28]. On the other hand, it is possible to underestimate the risk in children who, despite their relatively low body weight, have a high fat content dangerous to health [29]. The lack of unambiguous results regarding the relationship of prenatal stress with the occurrence of overweight and obesity may partly result from the use of BMI [20–24, 30–37] that is difficult to interpret in research, while the level of adipose tissue in this context has rarely been studied [38–41].

In this study, we have tested the hypothesis that children of mothers who experienced stress during pregnancy have an increased risk of obesity. As indicators we use BMI and the percentage of body fat measured with bioimpedance method.

2. Material And Methods

The study was conducted in 11 randomly selected schools in Poznań, Poland. The cohort study included 254 girls and 276 boys. The study was funded by the National Science Centre, Poland, grant number: 2016/21/B/NZ5/00492 and approved by the Institutional Bioethics Board of Poznan University of Medical Sciences (approval no. 542/14). The subjects and their legal guardians were fully informed about the research procedures and the legal guardians gave written consents to participate in the study. The data on prenatal maternal stress, body composition measurements as well as socioeconomic (SES) factors were collected for each child. Children from 6 to 12 years were examined. The children were divided into groups <9, 9-10 and >10 years and comparisons were made between these groups.

2.1 Maternal psychological stress

The parents or guardians of a 6–12-year-old child were asked if there were any adverse stressful events during the pregnancy. The questionnaire included questions about the subjective perception of stress related to objectively occurring problems like 1. difficult financial situation, 2. family problems, 3. illness or death of a family member, 4. abnormalities occurring during pregnancy, 5. other type of stressors.

2.2 Anthropometric measurements in children

Body height was measured with the anthropometer Seca 213, with measurement accuracy of ± 1 mm. Body weight was measured with the use of TANITA MC-780 MA S multi frequency segmental body composition analyzer with measurement accuracy of 100g. TANITA MC-780 MA S was also applied for body composition assessment. During the examination the children were barefoot and wearing light clothes. The children were measured between 8 a.m. and 2 p. m. in the nurse's offices in their schools by trained medical personnel. In our study, food consumption and exercise were not checked prior to the body composition analysis. However, as shown in previous studies, the effect of a meal on the analysis result was not clinically significant [42].

Body Mass Index (BMI, kg/m²) was calculated as body weight (kg) divided by square height (m²). BMI was adjusted for sex and age on the basis of World Health Organization (WHO) growth charts [43] with the use of WHO AnthroPlus software and presented as z scores. Overweight, obesity and underweight were diagnosed under the guidance of the International Obesity Task-Force [44, 45] and based on body fat cut-off points for the bioimpedance method [46].

2.3 Controlled factors

The following data related to the socio-demographic characteristics of the sample and maternal pre-pregnancy fatness were checked in the study:

Economic status – assessment of meeting needs of the family (possible answers: low / rather low / not very low / quite high / high).

Place of residence (possible answers: village / city up to 1,000 inhabitants / city of 10-50 thousand inhabitants / city of 50-100 thousand inhabitants / city of 100-500 thousand inhabitants / city of over 500 thousand inhabitants).

Maternal and paternal education level (possible answers: basic / vocational / secondary / higher).

BMI before pregnancy calculated according to the World Health Organization standards [16]; the mothers were divided into 4 groups based on their BMI (underweight with a BMI below 18.5 kg/m² / normal weight BMI 18.5-24.9 kg/m² / overweight BMI 25-29.9 kg/m² / obesity BMI over 30 kg/m²).

2.4 Statistical Analysis

Statistical analysis of the prevalence of underweight, overweight and obesity diagnosed according to IOTF references and diagnosed according to body fat cut-off points in relation to sex, age, place of residence, meeting the financial needs of the family, maternal BMI before pregnancy, the mother's and father's education were carried out using χ^2 test. The relationship between the BMI categories and categories of body fat content and prenatal stress was assessed by a logistic regression, where the BMI status and fat tissue status were used as a response variable and prenatal stress as a predictive variable. Two sets of models were tested: the unadjusted one and the adjusted one for sex, age, socioeconomic variables (the parents' education level and parental subjective assessment of socioeconomic situation of the family) and pre-pregnancy maternal BMI. Regression models were also constructed separately for the boys and girls. All the tests were performed with the Statistica (Version 13.3) software and considered to be statistically significant at $p < 0.05$.

3. Results

3.1 The selection procedure

The sample included 553 children aged 6–12 (mean=8.97, SD=1.28) in comparable proportion of boys (52.23%) and girls (47.76%). The written consent for the research was submitted by 553 children. Incomplete information on prenatal stress was the reason for excluding of 10 participants and 13 others were excluded from the analysis because of incomplete information on bioimpedance analysis. The final study group consisted of 530 children. Although in several cases the parents did not answer the questions about the size of place of residence (n=25, 4.71%), assessment of meeting financial needs (n=21, 3.96%), maternal pre-pregnancy BMI (n=17, 3.21%), the parents' level of education (mothers' education: n=10, 1.88% or fathers' education: (n=29, 5.47%), they were not excluded from the sample. The regression analysis of the models adjusted for the variables was limited to the cases with complete data (n=459, 86.60% of the sample). The basic characteristics of the sample are presented in table 1.

3.2 Occurrence of stress in the study group

One hundred and fifty-eight (30%) out of 530 children were exposed to at least one type of the stressors in prenatal life. One type of prenatal stressors was experienced by 131 (21%), two types by 50 children (9%) and three types by 19 children (3%). The most frequently experienced type of stressors during pregnancy was family problems (n=77, 14%) and the fear of the possible occurrence of abnormalities in the child (n=46, 9%) (table 1).

3.3 Sex and age differences in prenatal stress and body weight status

The description statistics of anthropometric measurements of the whole sample are presented in table 2.

There were no differences between boys and girls in the occurrence of underweight, overweight and obesity diagnosed according to IOTF (table 3). The significant differences between sexes were found when the body fat cut offs have been applied for the identification of individuals with underweight, normal weight, overweight and obesity ($\chi^2=14.438$, $p=0.0024$).

Overweight (16%) and obesity (20%) were more common in the boys (21%, 22%) than the girls (11%, 18%). The analyses do not indicate the existence of significant differences in the occurrence of underweight, overweight and obesity diagnosed on the basis of BMI between particular age groups (<9, 9-10 and >10 years- old). The significant differences between age groups were found when the body fat cut-offs have been applied for the identification of individuals with underweight, normal weight, overweight and obesity ($\chi^2=18.851$, $p=0.004$). Obesity diagnosed according to body fat cut-off points was more common among children under 9 years old (23%) and between 9 and 10 years old (20%) than children over 10 years old (12%, table 4).

3.4 Associations of socioeconomic factors and mothers' pre-pregnancy weight with the prevalence of improper body mass

The analysis of the relation between socioeconomic factors and underweight, overweight or obesity diagnosed on the basis of BMI showed a significant relationship with the mother's BMI before pregnancy ($\chi^2=53.643$, $p=0.000$), the mother's education ($\chi^2=31.038$, $p=0.0002$) and the father's education ($\chi^2=22.673$, $p=0.006$). The children of the mothers overweight before pregnancy were more often obese (18%) than the children of the mothers with normal body weight before pregnancy (4%, $\chi^2=22.520$, $p=0.000$). The mothers who were obese before pregnancy had more often children who were overweight (50%) than the mothers with normal weight (14.32%, $\chi^2=14.497$, $p=0.002$). The children of the mothers with the higher education level were less often obese (2%) than the children of the mothers with vocational education level (17%, $\chi^2=26.92$, $p=0.000$). The fathers with higher education level were less likely to have children overweight (12%, $\chi^2=9.918$, $p=0.019$) or obese (2%, $\chi^2=10.40$, $p=0.015$) than the fathers with a vocational education level (29%, 9%). Obesity was observed more frequently (40%, $\chi^2=16.154$, $p=0.02$) in the children whose parents declared great difficulties in meeting the financial needs of their families than in the children of the parents who did not declare difficulties (5%). The place of residence was not significantly associated with the frequency of abnormalities in body weight categories (table 5).

The analysis of the relation between socioeconomic factors and underweight, overweight and obesity diagnosed on the basis of body fat cut-off points showed a significant relationship with the mother's BMI before pregnancy, the mother's education and prenatal stress. Overweight (43%) was the most common in children of the mothers who were obese before pregnancy ($\chi^2=8.095$, $p=0.044$) (table 6). The children of the mothers who had higher education level were less likely obese (17%) than the mothers who had vocational education (31%, $\chi^2=7.882$, $p=0.048$). The children of the mothers who experienced stress during pregnancy were more often overweight (22%) than the children of the mothers who did not experience stress during pregnancy (14%, $\chi^2=4.273$, $p=0.038$).

3.5 Effects of prenatal stress on weight status

The unadjusted logistic regression analysis did not reveal any associations of prenatal stress (≥ 1 type vs 0) with underweight (OR=0.94, 95%CI: 0.50-1.72), overweight (OR=1.01, 95%CI: 0.58-1.75) and obesity (OR=0.94, 95%CI: 0.4-2.21) diagnosed according to IOTF. The analyses adjusted for other variables gave similarly insignificant results for underweight (OR=1.04, 95%CI: 0.52-2.05), overweight (OR=1.03, 95%CI: 0.58-1.83) and obesity (OR=0.81, 95%CI: 0.29-2.25). In separate analyses of the group of the boys and the group of the girls the relations between prenatal stress and status BMI were also statistically insignificant (table 7). However, the unadjusted logistic regression analysis revealed associations of prenatal stress (≥ 1 vs 0) with overweight (OR=1.65, 95%CI: 1.02-2.66) diagnosed according to body fat cut-off points. This result was confirmed in the analyses adjusted for other variables (OR=2.14, 95%CI: 1.25-3.67). A separate analysis in the group of boys, adjusted for other variables, confirmed the association of prenatal stress and overweight (OR = 2.44, 95% CI: 1.21-4.91) whereas, in a separate analysis for the girls the results were not statistically significant (table 8).

4. Discussion

The use of BMI is the easiest, fastest and cheapest method of the assessment of overweight and obesity. Unfortunately, BMI is not an indicator that perfectly reflects changes in the body proportions. In adult studies obesity assessment based on $\text{BMI} \geq 30 \text{ kg/m}^2$ does not include even more than half of the people with excessive body fat [47]. The excess of adipose tissue contributes to the development of diseases such as diabetes [48], hypertension [48, 49] or cancers, e.g. colorectal cancer [50] and breast cancer [51]. In order to avoid underestimating the number of children with excessive fat tissue the use of standards based on body fat cut-off points for overweight seems to be the solution of diagnosing adiposity more accurately than with use of BMI [29]. We can assume that thanks to the use of standards based on body fat cut-off points for overweight we may be able to identify the children with abnormal body composition changes potentially dangerous to their health, which have not yet caused any important increase in the BMI. By applying these standards we may be able to avoid incorrect underdiagnosis of overweight and obesity in children [52] and intervene by introducing appropriate nutritional management sooner.

The results of previous work are inconsistent. Some of them confirmed the relationship between prenatal stress and overweight [37] or obesity [22], but others demonstrated the relationship between prenatal stress and underweight in children [53]. We did not find the relation of prenatal stress with underweight in our research, and the results of the analysis of the association of prenatal stress and adiposity depended on the overweight and obesity assessment method. However, the results of our study do show that the prenatal stress was related to increased risk of overweight (OR 2.14, 95%CI: 1.25-3.65) diagnosed on the basis of body fat cut-off points, but not when the BMI was diagnostic criterion (OR 1.03, 95%CI: 0.58-1.83). These discrepancies are in line with the fact that BMI-based diagnosing of body weight status turns out to be underestimated in other studies. A Mexican study found a two-fold lower incidence of overweight in children when weight status was diagnosed based on BMI compared to body fat [29]. The results were confirmed in a meta-analysis, in which the diagnosis of obesity based on BMI failed to show some of the people with an increased content of adipose tissue in half of the cases [52]. Based on our results and above mentioned studies prenatal stress should be considered a risk factor for the development of excessive fat tissue and later obesity even if stress effect on BMI is insignificant among children aged 6-12.

Some inconsistent results of the previous research may also be caused by different methods of assessing prenatal stress. In most of the studies prenatal stress was examined during pregnancy and after a few years the anthropometric indicators in children were checked [22, 30, 39, 54]. However, there were also studies based on the survey filled in by the parents/caregivers retrospectively [24] which may have resulted in not remembering adverse life events that had occurred in the past.

The factor that links prenatal stress with the changes in the body fat of a child in postnatal life is probably the HPA axis (hypothalamus-pituitary-adrenal axis), which is particularly active in a stressful situation [55]. Under stress larger amounts of hormones are released, including adrenaline and cortisol. Cortisol is a hormone that in physiological conditions does not get through the placenta to the fetus because of a factor 11 β -Hydroxysteroid dehydrogenase type 2 (11 β -HSD2). 11 β -HSD2 makes 80-90% of the cortisol reaching the placenta transform into its inactive form – cortisone, thanks to which the fetus is protected from the adverse effects of cortisol [56]. Unfortunately, under the influence of chronic, very severe stress, there is a danger that same amount of cortisol enters the bloodstream of the fetus and may adversely affect the future health of the child disrupting the work of the HPA axis and affecting the hormones that regulate hunger and satiety in the child [19].

Among the examined children there are differences between the frequency of diagnosed overweight in the boys and girls who experienced prenatal stress. In the group of boys whose mothers experienced adverse life events in pregnancy overweight was almost 2.5-fold more common than among the boys who were not exposed to prenatal stress. There are no statistically significant relationships in the group of girls. This result may indicate that boys are more susceptible to the harmful effects of environmental factors, as stress. The results of other Polish studies confirm the more frequent occurrence of overweight among boys [57]. The incidence of overweight in the group of boys higher than in the girls may be due to a different way of spending their free time. Boys tend to spend more time than girls on sedentary activities, e.g. playing computer games [58]. Additionally, it can be assumed that girls are more exposed to social pressure regarding a slim figure [59], which is why overweight and obesity occur in girls less frequently.

In our study overweight and obesity diagnosed on the basis of IOTF standards are less common in the children of the mothers and fathers with higher education. Previous research shows that the level of parents' education is related to the food consumed by their children. The children of parents with low education more often ate foods with high content of sugar and fat than the children of parents with higher levels of education [60]. The mother's weight status before pregnancy also plays a role in developing a healthy body status in children. Results of our study show that the mothers who were overweight or obese before pregnancy had more often overweight or obese children, which is consistent with the results of other studies [61].

5. Conclusion

Prenatal stress is associated with an increased incidence of overweight diagnosed on the basis of body fat cut-off points. This method of diagnosing body fat level abnormalities in children seems to be a measure of the adverse effects of prenatal stress on the human body more sensitive than the use of standards based on BMI and may be recommended for future research on obesity risk factors. Further studies on the prenatal exposition to stress and body fat content as well as fat metabolism should be conducted.

Strength and limits

The advantage of our study is the use of two types of standards for the assessment of underweight, overweight and obesity. We used norms based on both BMI and based on the percentage of body fat. The use of body fat norms based on body fat appears to be a tool that will more accurately determine the actual number of children with abnormal body composition than BMI. To our knowledge, such a classification has not yet been used in any study dealing with the relationship between the body weight and prenatal stress. In addition, the analysis took into consideration the role of gender and socioeconomic status as modulators of the relationship between the prenatal stress and body weight. Despite the strengths of the study, there are also limitations that need to be considered. The study was cross-sectional with a parental retrospective an assessment of adverse experiences during pregnancy, which could lead the subjects to miss some events due to forgetfulness. We did not assess either the trimester in which the woman was exposed to stress, and we did not assess the duration of the exposure to adverse factors. Neither did we check the time of the children's last meal and physical activity prior to the body composition analysis.

What is already known on this subject?

The relationship between the prenatal stress and weight changes in children gives inconclusive results. Some studies have shown a relationship between prenatal stress and underweight, and others with overweight or obesity. More work is still needed to investigate this relationship.

What this study adds?

The study presents significant differences between the assessment of overweight and obesity based on two different diagnostic criteria.

Declarations

Author Contributions: Conceptualization, TH, MD-W and AS; methodology, TH, MD-W and AS; investigation, EB, PS, TH, AD, MD-W; data curation, EB; writing—original draft preparation, EB, TH; project administration, TH; funding acquisition, TH, MD-W, AS. All authors have read and agreed to the published version of the manuscript.”

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee Poznan University of Medical Sciences (approval no. 542/14).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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Tables

Table 1. Characteristics of the group

Variable	The information available for	category	N	%
Age	530	<9 years old	294	55
		9-10 years old	120	23
		>10 years old	116	22
Sex	530	girls	254	48
		boys	276	52
Place of residence	505	village	42	8
		city of up to 10 thousand residents	3	1
		city of 10 thousand up to 50 thousand residents	43	8
		city of 50 thousand up to 100 thousand residents	17	3
		city of 100 thousand up to 500 thousand residents	37	7
		city of over 500 thousand residents	363	69
Economic status – assessment of meeting needs	509	low	5	1
		rather low	14	3
		not very low	90	17
		quite high	235	44
		high	165	31
Maternal pre-pregnancy BMI	513	underweight	51	10
		normal weight	391	74
		overweight	57	11
		obesity	14	3
Mother's education level	520	primary	5	1
		vocational	52	10
		secondary	121	23
		higher	342	65
Father's education level	501	primary	15	3
		vocational	93	18
		secondary	146	28
		higher	247	47
The number of experienced prenatal stressors	530	1 type of stressors	131	21
		2 types of stressors	50	9
		3 types of prenatal stressors	19	3

The types of stressors	530	Financial problems	29	5
		Family problems	77	14
		Disease or death of a close relative	29	5
		Abnormalities during pregnancy	46	9
		Other	30	6
BMI status	530	underweight	56	11
		normal weight	366	69
		overweight	80	15
		obesity	28	5
FAT status	530	underweight	2	0.4
		normal weight	335	63.2
		overweight	87	16.4
		obesity	106	20

Table 2. Characteristic of the sample (anthropometric measurements) according to sex and age.

Sex	Age	N	Anthropometric measurements (Mean $\pm$ SD)			
			Height (cm)	Weight (kg)	BMI (kg/m ²)	Body fat (%)
Boys	6y	0	-	-	-	-
	7y	12	129.4 $\pm$ 7.2	28.0 $\pm$ 5.4	16.7 $\pm$ 2.7	22.5 $\pm$ 7.0
	8y	72	129.8 $\pm$ 5.1	28.4 $\pm$ 5.0	16.76 $\pm$ 2.1	22.1 $\pm$ 5.6
	9y	80	134.7 $\pm$ 5.6	31.2 $\pm$ 6.9	17.04 $\pm$ 2.9	22.1 $\pm$ 6.5
	10y	53	139.2 $\pm$ 6.1	34.5 $\pm$ 7.6	17.7 $\pm$ 3.1	22.6 $\pm$ 7.9
	11y	35	147.0 $\pm$ 6.2	40.1 $\pm$ 8.7	18.4 $\pm$ 2.9	22.1 $\pm$ 6.7
	12y	24	149.7 $\pm$ 7.9	42.4 $\pm$ 12.4	18.7 $\pm$ 4.2	20.6 $\pm$ 6.9
Girls	6y	1	125	32.3	20.7	33.6
	7y	14	123.8 $\pm$ 4.8	24.2 $\pm$ 3.7	15.7 $\pm$ 1.7	23.3 $\pm$ 5.5
	8y	76	129.0 $\pm$ 5.1	27.3 $\pm$ 5.6	16.3 $\pm$ 2.4	24.5 $\pm$ 5.8
	9y	70	133.9 $\pm$ 5.0	31.1 $\pm$ 6.4	17.2 $\pm$ 2.7	25.8 $\pm$ 6.0
	10y	61	139.3 $\pm$ 6.4	33.3 $\pm$ 8.7	17.0 $\pm$ 3.3	24.3 $\pm$ 7.6
	11y	20	145.4 $\pm$ 8.6	40.6 $\pm$ 8.4	19.1 $\pm$ 2.8	25.0 $\pm$ 4.8
	12y	12	149.0 $\pm$ 7.7	38.9 $\pm$ 6.4	17.5 $\pm$ 2.3	23.4 $\pm$ 4.3

* BMI – Body Mass Index, y - years

Table 3. Prevalence of underweight, overweight and obesity diagnosed according to IOTF references in the group of children divided according to sex and age (χ^2).

	underweight		normal weight		overweight		obesity		χ^2 , p
	N	%	n	%	n	%	n	%	
Total	56	11	366	69	80	15	28	5	
Boys	21	8	195	71	47	17	13	5	6.765, 0.08
Girls	35	14	171	67	33	13	15	6	
<9-year- olds)	35	12	205	70	39	13	15	5	2.967, 0.814
9-10-year- olds	11	9	80	67	22	18	7	6	
>10-year- olds	10	9	81	70	19	16	6	5	

Table 4 Prevalence of underweight, overweight and obesity diagnosed according to body fat cut-off points in the group of children divided according to sex and age (χ^2).

	underweight		normal weight		overweight		obesity		χ^2 , p
	n	%	n	%	n	%	N	%	
Total (533)	2	0.3	335	63	87	16	106	20	
Boys (n=278)	1	0.3	155	56	59	21	61	22	14.438, 0.002
Girls (n=255)	1	0.0	180	71	28	11	45	18	
<9-year- olds (n=296)	0	0	170	58	56	19	68	23	18.851, 0.004
9-10-year- olds (n=121)	0	0	83	69	13	11	24	20	
>10-year- olds (n=116)	2	2	82	71	18	16	14	12	

Table 5. Characteristics of socioeconomic environment of the studied groups of children and associations between these factors and the prevalence of underweight and overweight diagnosed according to IOTF (χ^2).

	underweight		normal weight		overweight		Obesity		χ^2 , p
	n	%	n	%	n	%	n	%	
Place of residence									
Village	8	19.05	29	69.05	4	9.52	1	2.38	22.685, 0.091
City of up to 10 thousand residents	0	0	1	33.3	2	66.67	0	0	
City of 10 thousand up to 50 thousand residents	2	4.65	32	74.42	7	16.28	2	4.65	
City of 50 thousand up to 100 thousand residents	2	11.76	10	58.82	2	11.76	3	17.65	
City of 100 thousand up to 500 thousand residents	5	13.51	21	56.76	7	18.92	4	10.81	
City of over 500 thousand residents	37	10.19	259	71.35	51	14.05	16	4.41	
χ^2 , p*	5.496, 0.358		6.69, 0.244		8.299, 0.140		9.118, 0.104		
Economic status – assessment of meeting needs									
low	0	0	2	40	1	20	2	40	19.732, 0.072
rather low	1	7.14	10	71.43	3	21.43	0	0	
not very low	11	12.22	55	61.11	16	17.78	8	8.89	
quite high	26	11.06	165	70.21	35	14.89	9	3.83	
high	18	10.91	119	72.12	20	12.12	8	4.85	
χ^2 , p*	0.970, 0.914		5.531, 0.237		2.174, 0.707		16.154, 0.002		
Maternal pre-pregnancy BMI									
Underweight	14	27.45	29	56.86	8	15.69	0	0	53.643, 0.000
Normal weight	39	9.97	281	71.87	56	14.32	15	3.84	
Overweight	2	3.51	39	68.42	6	10.53	10	17.54	
Obesity	1	7.14	5	35.71	7	50	1	7.14	
χ^2 , p*	18.116, 0.000		12.276, 0.006		14.497, 0.002		22,520, 0.0000		
Mother educational level									
Primary	0	0	3	60	1	20	1	20	31.038, 0.000
Vocational	3	5.77	30	57.69	10	19.23	9	17.31	
Secondary	15	12.40	76	62.81	20	16.53	10	8.26	
Higher	36	10.53	250	73.10	49	14.33	7	2.05	
χ^2 , p*	2,303, 0,511		8.157, 0.0428		1.088, 0.779		26.92, 0.00001		
Father educational level									

Primary	1	6.67	10	66.67	2	13.33	2	13.33	22.673, 0.006
Vocational	7	7.53	54	58.06	24	28.81	8	8.60	
Secondary	13	8.90	102	69.86	21	14.38	10	6.85	
Higher	30	12.15	182	73.68	30	12.15	5	2.02	
χ^2 , p*	2.222, 0.527		7.837, 0.049		9.918, 0.019		10.40, 0.015		
Prenatal stress									
no	40	10.75	256	68.82	56	15.5	20	5.38	0.073, 0.994
yes	16	10.13	110	69.62	24	15.19	8	5.06	
χ^2 , p*	0.046, 0.830		0.033, 0.854		0.001, 0.968		0.022, 0.882		

* χ^2 tests results for each body weight category (underweight, normal weight, overweight and obesity) compared to the rest of the studied group

Table 6. Characteristics of socioeconomic environment of the studied group of children and associations between these factors and the prevalence of underweight and overweight diagnosed according to body fat cut-off points (χ^2).

	underweight		normal weight		overweight		obesity		χ2, p
	n	%	n	%	n	%	n	%	
Place of residence									
Village	0	0	25	59.52	5	11.90	12	28.57	21.644, 0.117
City of up to 10 thousand residents	0	0	1	33.33	1	33.33	1	33.33	
City of 10 thousand up to 50 thousand residents	0	0	32	74.42	5	11.63	6	13.95	
City of 50 thousand up to 100 thousand residents	1	5.88	9	52.94	2	11.76	5	29.41	
City of 100 thousand up to 500 thousand residents	0	0	21	56.76	7	18.92	9	24.32	
City of over 500 thousand residents	1	0.28	231	63.64	63	17.36	68	18.73	
χ2, p*	13.602, 0.018		5.179, 0.394		2.634, 0.756		4.982, 0.418		
Economic status – assessment of meeting needs									
low	0	0	3	60	0	0	2	40	10.018, 0.614
rather low	0	0	10	71.43	1	7.14	3	21.43	
not very low	1	1.11	52	57.78	18	20.00	19	21.11	
quite high	1	0.43	162	68.94	32	13.62	42	17.02	
high	0	0	99	60	30	18.18	36	21.82	
χ2, p*	1.918, 0.750		5.516, 0.238		4.434, 0.350		2.281, 0.560		
Maternal pre-pregnancy BMI									
Underweight	2	3.92	31	60.78	6	11.76	12	23.53	36.830, 0.000
Normal weight	0	0	260	66.50	62	15.86	69	17.65	
Overweight	0	0	33	56.90	10	17.54	14	25.56	
Obesity	0	0	2	14.29	6	42.86	6	42.86	
χ2, p*	18.188, 0.000		17.088, 0.001		8.095, 0.044		7.115, 0.06		
Mother educational level									
Primary	0	0	3	60	1	20	1	20	10.815, 0.288
Vocational	0	0	27	51.92	9	17.31	16	30.77	
Secondary	1	0.83	76	62.81	14	11.57	30	24.79	
Higher	1	0.29	222	64.91	62	18.13	57	16.67	
χ2, p*	0.912, 0.822		3.296, 0.348		2.855, 0.414		7.882, 0.048		
Father educational level									

Primary	0	0	10	66.67	1	6.67	4	26.67	7.344, 0.601
Vocational	0	0	55	59.14	15	16.13	23	24.73	
Secondary	0	0	90	61.64	22	15.07	34	23.29	
Higher	1	0.40	163	65.99	44	17.81	39	15.79	
χ2, p*	1.030, 0.793		1.705, 0.635		1.592, 0.661		5.448, 0.141		
Prenatal stress									
No	1	0.27	247	66.40	53	14.25	71	19.09	6.49, 0.089
Yes	1	10.63	88	55.70	34	21.52	35	22.15	
χ2, p*	0.391, 0.531		5.461, 0.019		4.273, 0.038		0.651, 0.419		

* χ^2 tests results for each body weight category (underweight, normal weight, overweight and obesity) compared to the rest of the studied group

Table 7. Logistic regression models of underweight, overweight and obesity diagnosed according to IOTF and prenatal stress.

Body weight abnormalities (IOTF norms)

		Total				Boys				Girls			
		OR	95%CI	Wald Chi2	p	OR	95%CI	Wald Chi2	p	OR	95%CI	Wald Chi2	p
Models for underweight determination													
1	Prenatal stress (1-yes, 0-no) unadjusted	0.94	0.50-1.72	0.045	0.830	0.89	0.33-2.39	0.052	0.818	0.99	0.37-2.61	0.000	0.984
2	prenatal stress adjusted*	1.04	0.52-2.05	0.013	0.908	1.00	0.32-3.22	0.000	0.987	1.10	0.44-2.74	0.049	0.823
Models for overweight determination													
1	Prenatal stress (1-yes, 0-no) unadjusted	1.01	0.58-1.75	0.001	0.969	1.2	0.61-2.34	0.279	0.597	0.77	0.33-1.8	0.372	0.541
2	Prenatal stress adjusted*	1.03	0.58-1.83	0.014	0.904	1.68	0.76-3.68	1.696	0.192	0.70	0.27-1.82	0.533	0.465
Models for obesity determination													
1	Prenatal stress (1-yes, 0-no) unadjusted	0.94	0.4-2.21	0.021	0.884	0.39	0.08-1.83	1.420	0.232	1.71	0.58-5.01	0.967	0.325
2	Prenatal stress adjusted*	0.81	0.29-2.25	0.156	0.692					1.82	0.53-6.25	0.914	0.33

**Adjusted for age, sex, place of residence, maternal pre-pregnancy BMI, parental assessment of income, parental education*

Table 8 Logistic regression models of underweight, overweight and obesity diagnosed according to body fat cut-off points.

Body fat abnormalities (McCarthy et al criteria)

		Total				Boys				Girls			
		OR	95%CI	Wald Chi ²	p	OR	95%CI	Wald Chi ²	p	OR	95%CI	Wald Chi ²	p
Models for underweight determination													
1	Prenatal stress (1-yes, 0-no) unadjusted	2.36	0.15-38.27	0.37	0.544								
Models for overweight determination													
1	Prenatal stress (1-yes, 0-no) unadjusted	1.65	1.02-2.66	4.22	0.04	1.59	0.873-2.919	2.33	0.126	1.71	0.756-387	1.68	0.195
2	Prenatal stress adjusted*	2.14	1.25-3.67	7.48	0.005	2.44	1.21-4.91	6.28	0.01	1.79	0.72-4.431	1.58	0.208
Models for obesity determination													
1	Prenatal stress (1-yes, 0-no) unadjusted	1.21	0.76-1.9	0.65	0.42	1.13	0.610-2.075	0.14	0.703	1.30	0.650-2.603	0.561	0.454
2	Prenatal stress adjusted*	1.14	0.68-1.92	0.26	0.607	1.03	0.491-2.16	0.006	0.936	1.25	0.585-2.687	0.34	0.559

**Adjusted for age, sex, place of residence, maternal pre-pregnancy BMI, parental assessment of income, parental education*