Somatic traits of the mother, her weight gain during pregnancy as well as blood parameters, versus infant birth parameters

Cechy somatyczne matki, przyrost masy ciała w czasie ciąży oraz parametry krwi a parametry urodzeniowe noworodka

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Słowa kluczowe: noworodki, ciążowy przyrost masy ciała, parametry urodzeniowe noworodka.

Abstract

Introduction: The female body creates specific conditions for the growth of a foetus during pregnancy. It is important to assess a mother's anthropometric and physiological parameters in the context of the development of particular parameters of the newborn in order to better monitor the course of pregnancy. One of such parameter is a woman's body mass before pregnancy and its increase during pregnancy. Currently, overweight and obesity are a major problem in women of childbearing age.
Aim of the research: To assess the relationship between the mother's anthropometric features, selected haematological indicators, and smoking during pregnancy, and birth parameters in her child.
Material and methods: A cohort study was conducted among 403 women with singleton pregnancy, who were admitted into the Obstetrics and Gynaecology Clinic at the Regional Polyclinical Hospital in Kielce (Poland). Data about the women and their newborns were collected using a survey questionnaire, anthropometric measurements, and medical documentation. The following parameters of the newborns were registered: body length, head circumference, and Apgar score at one minute after birth. Among the newborns, 52.11% were boys and 47.89% were girls.
Results and conclusions: One-fourth of the women entered pregnancy with excessive weight or obesity. Multiple regression analysis showed that the mother's somatic traits explained 13% of the variance of body mass, 9% of body length at birth, and 8% of the newborn's head circumference. An excessive increase in mother's body mass during pregnancy was associated with increased parameters of the newborn compared to mothers with a normal increase in body mass.

Streszczenie

Wprowadzenie: Organizm kobiety stwarza określone warunki dla wzrostu dziecka w czasie ciąży. Badania parametrów antropometrycznych lub fizjologicznych matki w zakresie rozwoju określonych cech noworodka są ważne m.in. ze względu na możliwość lepszego kontrolowania przebiegu ciąży. Masa ciała kobiety przed ciążą i jej przyrosty w trakcie ciąży stanowi jeden z takich czynników. Obecnie nadwaga i otyłość to poważny problem kobiet w okresie rozrodczym.
Cel pracy: Ocena zależności między cechami antropometrycznymi, wybranymi wskaźnikami hematologicznymi kobiet oraz paleniem papierosów w czasie ciąży i wielkością parametrów urodzeniowych u ich dzieci.
Materiał i metody: W badaniu kohortowym wzięły udział 403 kobiety z ciążą pojedynczą, zgłaszające się do Kliniki Położnictwa i Ginekologii Wojewódzkiego Szpitala Zespolonego w Kielcach (Polska). W badaniu wykorzystano dane kobiet i noworodków zebrane za pomocą kwestionariusza wywiadu, pomiarów antropometrycznych oraz dokumentacji medycznej. Uwzględniono następujące parametry niemowlęcia: masę urodzeniową, długość ciała, obwód głowy oraz punktację Apgar w 1. minucie po urodzeniu. Wśród noworodków 52,11% stanowili chłopcy, a 47,89% dziewczynki.

Wyniki i wnioski: Jedna czwarta kobiet rozpoczynała ciążę, mając nadwagę lub otyłość. Wyniki analizy regresji wielorakiej wykazały, że cechy somatyczne matek wyjaśniały w 13% zmienność masy ciała, a w 9% długość urodzeniową i 8% obwód głowy noworodków. Zbyt duży przyrost masy ciała stwierdzany u matek w ciąży wiązał się z większymi pomiarami cech dziecka (masą ciała, długością ciała i obwodem głowy) w porównaniu z pomiarami noworodków matek o prawidłowym przyroście masy ciała.

Introduction

The birth parameters of a newborn constitute an important information database about his/her health and development potential, and also demonstrate the process of prenatal development. They provide evidence on the intrauterine environment of the mother. Her features, such as fat deposition in the body, metabolism, age, and the course of previous pregnancies, including gestational diabetes mellitus [1] form a set of unique factors impacting the developing embryo and foetus [2].

It has been observed that the weight of an infant, in consecutive pregnancies, is higher, while younger mothers give birth to smaller newborns. Taller women with higher muscle mass more frequently have infants with greater body length or birth weight [3]. In the case of shorter women, the risk of premature birth is higher than for tall mothers [4]. Apart from the physical characteristics of the mother, her lifestyle and, most of all, her health behaviours, both positive and negative, influence her infant's health. Exposure to tobacco smoke is mentioned as one of the key factors impacting unfavourably on a newborn's organism. A mother who actively or passively smokes increases the risk of giving birth to an infant with a low birth weight or with cerebral cortex development problems or infantile pneumonia [5–7].

The weight of women before pregnancy, as well as gestational weight gain, seems to be of great importance for the success of reproduction. At present, obesity and overweight is a serious problem among women in the reproductive period. For example, it applies, respectively, to over 26% and 22% of women in the USA, 18% and 6% of Chinese women [8], 20.9% and 10.7% of Uruguayan women [9], and in the case of Polish women it is 24.0% and 8.9% [10].

This indicates that some women begin their pregnancy with excessive weight gain, which increases the risk of gestational diabetes mellitus and other metabolic disorders [11–13]. Apart from the fat level before pregnancy, weight gained during pregnancy also influences the health condition of the mother and her child [14, 15]. The Institute of Medicine [16] in the U.S. in 2009 provided information on recommended weight gain levels, depending on the body mass index (BMI) indicator before the pregnancy. The more overweight a woman is, the less weight she should gain. The age of a mother and her BMI are the main factors connected to weight gain during pregnancy [17]. Excessive, gestational weight gain applies to over half of pregnant women (50.4% in the United States, 57.1% in China) [8] and has been associated with high birth weight of infants, pre-eclampsia, increased rates of Caesarean section [18, 19], and long-term effects such as the risk of obesity for babies in their future lives [14, 20] and elevated diastolic blood pressure [21]. Excessive weight gain also poses a danger to the mother and is frequently connected with gestational diabetes mellitus, high blood pressure, obesity, and other adverse conditions [22]. On the other hand, it was observed that insufficient weight gain increases the risk of low birth weight (LBW), small for gestational age infants (SGA), or even an increased risk of death in newborns [23].

Aim of the research

The aim of the study was to assess the relationship between anthropometric features, selected haematological indicators, smoking during pregnancy, and birth parameters in their children.

Material and methods

The research was conducted among 458 women and their newborns, who were patients at the Obstetrics and Gynaecology Clinic at the Regional Polyclinical Hospital in Kielce (Poland). The hospital provides care for female patients from the whole of the Świętokrzyskie region. The material was collected in 2014 and 2020. Further analysis excluded women who had given birth to twins (4 women) and those in whom the birth was premature (51 women). In total, the research included 403 women and their infants; 237 and 166 women were examined in 2014 and 2020, respectively.

The original survey questionnaire served as a tool for collecting information from the new mothers interviewed, regarding their social conditions such as their place of residence, education level, and their health behaviours, including smoking and eating habits, during pregnancy. The paper included only the influence of smoking habit at pregnancy; the issue of eating habits was described in previous papers [24, 25].

Data on premature childbirth and pregnancy-related information, such as the mode of delivery, blood physiological parameters (haemoglobin concentration in g/dl defined in 1st, 2nd, and 3rd pregnancy trimester and the value of glucose in mg% in the 1st trimester) as well as weight gain, during pregnancy, along with the newborns' parameters, were sourced from the medical documentation and survey questionnaires.

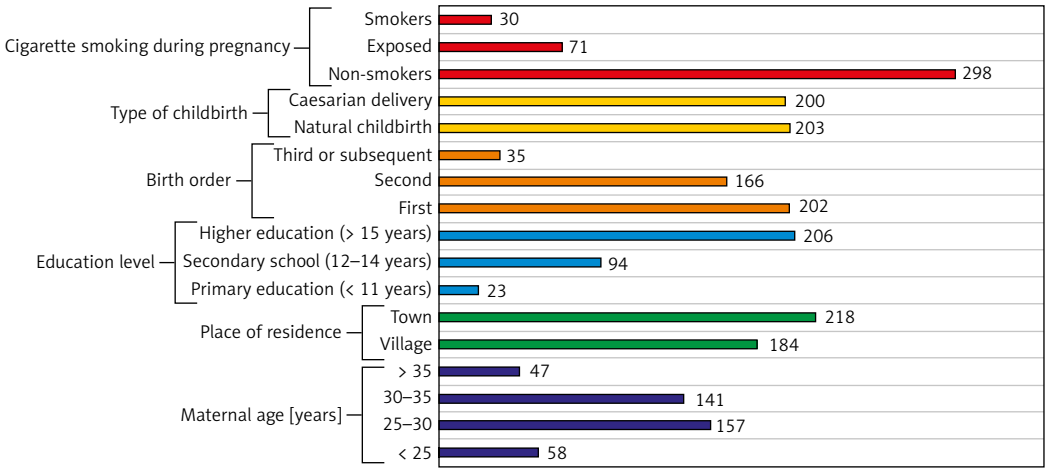

Figure 1. Characteristics of the studied women (number)

The first measurements of mothers were taken in the first trimester of pregnancy (between the 7th and the 9th week); the second round was repeated between the 23rd and the 24th week, while the third round was taken immediately before the birth of the child. During the first medical visit, measurements of the body height in centimetres as well as the weight in kilograms were collected in line with the guidelines (WHO 1995). An electronic medical scale with a telescopic height measuring device was used to measure body weight and height. The data were used to calculate the BMI (kg/m^2). Women were divided into BMI categories following WHO recommendations (1995): < 18.50 kg/m^2 (underweight); 18.50–24.99 kg/m^2 (normal weight); 25.00–29.99 kg/m^2 (overweight); and ≥ 30.00 kg/m^2 (obese). Weight gain during the first 3 months of pregnancy is low, usually being around 1–2%, which is assumed to be equivalent to the weight of the woman before pregnancy [26]. The difference between the weight from the first measurement and that before childbirth is defined as the total weight gain during pregnancy. In line with the recommendations of the Institute of Medicine (IOM) and the National Academy of Sciences (NAS) in the U.S., weight gain during pregnancy should correspond to the level of weight of a woman before pregnancy and should not exceed the guidelines.

The study was approved by the Bioethics Committee of Collegium Medicum Jan Kochanowski University of Kielce (15/2021).

Statistical analysis

Statistical analysis was carried out using Statistica 13.0 (StatSoft). Basic data are presented as mean and standard deviation (SD). Differences between women with recommended, low, or high weight gain during pregnancy were estimated using analysis of variance (ANOVA) with post-hoc test HSD – *Honestly Significant Difference by Tukey*. Spearman's correlation coefficients were used to determine the linear relationship between body mass, length, and head circumference of newborns (for the whole group and separately for each sex) and features of mothers. The impact of maternal body features as well as glucose and haematological parameters, and cigarette smoking during pregnancy on newborn traits was evaluated by means of multiple regression analysis. A probability *p*-value of less than 0.05 was considered significant.

Results

Figure 1 presents the basic characteristics of mothers participating in the research. Women living in cities constituted over half of all those interviewed (54.23%), while those living in the countryside amounted to 45.77%. Almost 2/3 of mothers had higher education (over 15 years of education) and only 7.12% had lower education level (11 years or fewer of education). Most women declared that they did not smoke and had not been exposed to tobacco smoke (74.69%); however, 30 women confirmed they smoked (7.52%) while 17.79% of the interviewed women had been exposed to smoke.

The average age of the interviewed women was 29.79 years. Most women had children at ages between 25.00 and 29.99 (38.96%), the next group between 30.00 and 34.99 (34.99%), and the least frequent motherhood age was noted among women over 35 years old (11.66%). For half of the women this was their first childbirth (50.12%) while only for 8.69% it was their 3rd child or more; however, the vast majority had given birth to their previous child within 3 years prior to the research. Only half of pregnancies ended in natural childbirth (50.37%). In the case of 44% of patients, caesarean section was pre-planned, and for over 5% the caesarean section resulted from perinatal complications. Over 70% of women started

Table 1. Descriptive statistic of anthropometric traits and the Apgar scale of newborns

Variable	*n* *N* = 403	Mean (SD)	Min.–max. or %
Birth weight [g]:			
All		3466.13 (406.18)	2430–4820
Boys	210	3422.83 (420.36)	2430–4550
Girls	193	3513.16 (384.66)	2650–4820
< 2500	1		0.25
2500–4000	360		89.33
> 4000	42		10.42
Birth length [cm]:			
All		54.59 (2.43)	47–67
Boys	210	54.59 (2.43)	49–65
Girls	193	54.80 (2.44)	47–67
Head circumference [cm]:			
All		34.71 (1.62)	30–39
Boys	210	34.65 (1.33)	30–38
Girls	193	34.84 (1.33)	30–39
Apgar scores [points]:	All group		
10–8	377		93.55
< 7	26		6.45

their pregnancy with correct body weight. Excessive weight or obesity was observed in the case of a quarter of the women. Weight gain, in relation to the BMI indicator, was in line with guidelines in a group of 140 (35.81%) women, too low for 112 of them (28.64%), and too high for 139 (35.55%) of them. This work also analyses the biochemical parameters of pregnant women, including haemoglobin concentration (g/dl) defined in the 1st, 2nd, and 3rd trimester of pregnancy, as well as the value of glucose in mg% in the first trimester.

The following infant parameters were considered: birth weight, body length, head circumference, and the Apgar score, in the 1st minute after birth. Among newborns 52.11% were boys and 47.89% girls. Most were born in good or very good condition; in the first minute after delivery the Apgar score was 6 or less for 14 infants (3.47%), 7–8 for 36 newborns (8.94%), and 9–10 for 353 infants (87.59%). Lower average birth weight was observed in the case of male infants (3422.83 g) while in the case of female infants it was (3513.16 g). Female newborns also had greater average body length and head circumference (Table 1).

When applying the analysis to the sex of newborns, correlations were observed in all the discussed parameters for boys but only in the case of body weight and head circumference for girls (Table 2). Smoking correlated negatively with all parameters of infants, with a statistical significance being noted in the category of body length; when related to gender, this applied only to boys. In reference to all of the newborns, the order of childbirths correlated visibly with body length. Considering the gender of the infants, the correlation applied only to boys (Table 2).

The dependencies observed were also confirmed with the use of multiple regression analyses (Table 3). The somatic indicators of the analysed newborns showed dependence on maternal parameters. The somatic features of the mothers explained, to a great extent, the variance in the body weight of infants (13%), the slightly shorter body length at birth (9%), and the head circumference (8%). The mother's body height, BMI, and weight gain during pregnancy were strongly related to the newborn's birth weight. However, no correlations were observed in the case of maternal smoking and birth weight or head circumference, while the most significant dependence was noted for an infant's body length. The result of the study showed that the birth weight and height of the infant was influenced by the mother's height, which could be dictated by chance and occurred in the study group.

In analysing the combination of maternal parameters, in relation to an infant's gender, it is worth mentioning that in the group of boys, significant statistical dependencies were observed in all the parameters examined, with larger variations than in the group

Table 2. Correlations between the characteristics of mothers and the characteristics of children

Maternal feature	Newborns' features								
	All			Boys			Girls		
	Birth weight	Stature length	Head circumference	Birth weight	Stature length	Head circumference	Birth weight	Stature length	Head circumference
Maternal weight gain	0.25**	0.13*	0.20**	0.34**	0.26**	0.22**	0.15*	–0.02	0.19*
Pre-pregnancy BMI	0.24**	0.10*	0.22**	0.31**	0.17*	0.24**	0.14	0.02	0.19**
End of pregnancy BMI	0.28**	0.11*	0.23**	0.36**	0.21**	0.24**	0.18*	–0.02	0.21**
Body height	0.13*	0.18**	0.13*	0.18*	0.11	0.21**	0.06	0.24**	0.04
Cigarette smoking	–0.3	–0.11*	–0.02	–0.10	–0.19**	–0.07	0.03	–0.04	0.03
Maternal age	0.01	0.07	–0.02	–0.04	0.01	–0.04	0.07	0.14	–0.01
Birth order	–0.03	0.12*	–0.02	0.05	0.18*	0.03	–0.10	0.05	–0.08
I Hb	0.11*	0.04	0.01	0.15*	0.06	0.02	0.05	0.01	0.02
II Hb	–0.09	–0.05	–0.10	–0.05	0.03	–0.08	–0.15*	–0.15*	–0.11
III Hb	–0.02	0.06	–0.01	0.09	0.18*	0.11	–0.15*	–0.07	–0.16*
Glucose	0.02	0.04	–0.03	0.07	0.04	0.00	–0.02	0.03	–0.05

*Spearman's rank correlation coefficient, *p < 0.05; **p < 0.01; BMI – body mass index; I Hb, II Hb, III Hb – haemoglobin in 1st, 2nd, and 3rd pregnancy trimester.*

of girls. The birth parameters of the boys correlated with maternal parameters better than was the case for girls (Table 4). For example, the variables investigated proved significant in understanding the variety of boys' head circumferences but were not statistically sufficient in the case of female infants.

Women whose weight gain was too high in relation to recommended values were characterised by higher values of the BMI indicator before pregnancy and a higher level of glucose in the fasting glucose test (Table 5). Also, a newborn's parameters, such as body weight, length, and head circumference, were significantly higher than in the newborns of mothers with the recommended weight gain during pregnancy.

Discussion

Weight gain during pregnancy is an important indicator of the mother's health as well as that of her child. On the one hand, too little or too much weight gain can pose a risk of anaemia, gestational diabetes mellitus, and high blood pressure and, for an infant, a high or a low birth weight. The age of the mother seems to be a factor generating variances in the weight level gained during pregnancy.

The research proved the relationship between the mother's traits and the birth parameters of her child. The greatest significance was noted in the case of weight gain during pregnancy and the values of the BMI indicator at the beginning of pregnancy.

Among women participating in the research, 25.06% were obese or overweight before pregnancy, which was similar to that observed in the works of Wojtyla [27]. A higher risk of a high birth weight was noted in the case of mothers who were either overweight or obese [28, 29]. However, not all the material indicates that the infant's condition was dependent on the mother's features; such a correlation was observed by Otero-Naveiro *et al.* [30]. The authors stated that the level of the development of somatic features in infants born to overweight or obese mothers was not different from those born to mothers with a normal body weight.

The analysis was based on examining infants from single pregnancies according to Naegelli's Rule. The vast majority were infants with correct birth weights between 2500 g and 4000 g. Newborns with macrosomia constituted 10.42% of the population examined. The risk of infant macrosomia seems to be higher in cases of overweight or obese mothers than it does in women with normal body weight [18, 31]. Macrosomia relates to a series of health problems in women. It was observed that giving birth to a child with macrosomia with no other symptoms and with the correct weight gain during pregnancy increases the risk of gestational diabetes mellitus in the next pregnancy [1]. Too little or too much weight gain during pregnancy or obesity during pregnancy can modify maturation of the foetus

Table 3. Multiple linear regression analysis of maternal and neonatal characteristics for all children

Newborn features	Maternal features								
	Maternal age	Prepregnancy BMI	Body height	Maternal weight gain	Cigarette smoking	Glucose	I Hb	II Hb	III Hb
Birth weight									
	R^2 = 0.13, F = 4.73, p < 0.01								
t	–0.03	2.66**	2.12*	3.55**	–0.85	–0.79	2.15*	–2.10*	–0.44
Birth length									
	R^2 = 0.09, F = 17.3, p = 0.02								
t	1.24	1.13	3.10**	2.11*	–1.56	–0.12	0.78	–1.91	1.39
Head circumference									
	R^2 = 0.08, F = 2.76, p = 0.004								
t	–0.71	2.43*	1.11	2.77**	–1.35	–1.60	0.64	–1.13	–0.36

*R^2 – multiple determination coefficients; F – statistic of the analysis of variance for the entire model; t – value of Student's statistic for each feature in the model; *p > 0.05, **p > 0.01; BMI – body mass index; I Hb, II Hb, III Hb – haemoglobin in 1st, 2nd, and 3rd pregnancy trimester.*

Table 4. Multiple linear regression analysis of maternal and neonatal characteristics by gender

Newborn features	Maternal features								
	Maternal age	Pre-pregnancy BMI	Body height	Maternal weight gain	Cigarette smoking	Glucose	I Hb	II Hb	III Hb
	Birth weight								
Boys	R^2 = 0.44, F = 4.01, p < 0.001								
	t = –1.10	1.51	1.22	3.46**	–1.24	0.07	1.41	–2.06*	1.04
Girls	R^2 = 0.11, F = 1.82, p = 0.071								
	t = 1.14	1.92	1.28	1.40	0.17	–0.97	0.93	–0.42	–1.78
	Birth length								
Boys	R^2 = 0.16, F = 3.13, p = 0.02								
	t = –0.20	0.80	0.39	3.38**	–2.44*	–0.50	–0.08	–1.53	1.90
Girls	R^2 = 0.12, F = 2.01, p = 0.043								
	t = 2.27*	0.71	3.46**	–0.37	0.26	0.10	0.97	–1.04	0.46
	Head circumference								
Boys	R^2 = 0.11, F = 2.04, p = 0.038								
	t = –0.99	2.21*	1.30	1.86	–0.35	–0.53	–0.53	–0.56	1.24
Girls	R^2 = 0.10, F = 1.65, p = 0.109								
	t = –0.31	1.50	0.31	1.96	–1.22	–1.39	1.29	–1.21	–1.14

*R^2 – multiple determination coefficients; F – statistic of the analysis of variance for the entire model; t – value of Student's statistic for each feature in the model; *p > 0.05, **p > 0.01; BMI – body mass index; I Hb, II Hb, III Hb – haemoglobin in 1st, 2nd, and 3rd pregnancy trimester.*

and influence its development, not only in the prenatal period but also by modification of the gene expression defining the metabolism of the child in the subsequent stages of his/her life [32]. In the research presented, in the case of more than one-third of women, too much weight gain was observed, while over 28% of women had insufficient weight gain, and this had a significant impact on the infant's birth weight.

Birth weight is not the only important factor defining the infant's health condition. Other somatic indicators, equally impactful, include the circumference of the head and/or body length. However, their dependence upon the mother's features is lower than in the case of birth weight. Moreover, it was proven that the mother's height can also modify the infant's parameters, most of all his/her body length at birth.

Table 5. Weight gain in pregnancy in relation to the characteristics of the mother and her newborn (ANOVA)

Variable	Gestational weight gain	Mean (SD)	*F*	*p* HSD
Maternal age [years]	Low	30.41 (4.32)	1.90	0.151
	Recommended	29.59 (4.52)		
	High	29.37 (4.95)		
Pre-pregnancy BMI [kg/m^2]	Low	21.75 (2.41)	26.31	< 0.001 L-H, R-H
	Recommended	23.01 (3.52)		
	High	25.14 (4.71)		L-H
Glucose [mg%]	Low	78.81 (10.80)	6.17	0.002
	Recommended	80.76 (8.51)		
	High	83.42 (9.81)		L-H
Hb I [g/dl]	Low	12.83 (1.01)	2.24	0.108
	Recommended	13.05 (0.84)		
	High	13.04 (0.83)		
Hb II [g/dl]	Low	11.91 (0.77)	3.12	0.045
	Recommended	12.14 (0.68)		
	High	12.12 (0.84)		L-R
Hb III [g/dl]	Low	12.13 (0.83)	1.67	0.189
	Recommended	12.29 (0.87)		
	High	12.33 (0.88)		
Birth weight [g]	Low	3343.96 (361.97)	12.15	< 0.001 L-H, R-H
	Recommended	3442.43 (382.31)		
	High	3587.16 (428.50)		
Birth length [cm]	Low	54.08 (2.26)	5.07	0.007
	Recommended	54.81 (2.02)		
	High	55.04 (2.89)		L-H, L-R
Head circumference [cm]	Low	34.20 (2.15)	8.80	< 0.001
	Recommended	34.76 (1.32)		
	High	35.04 (1.30)		L-H, L-R

F – analysis of variance; p – significance level of F. Significance of the HSD test between the groups L – low, R – recommended, H – high weight gain in pregnancy.

An observational study analysed 2.2 million singletons from Germany and showed that the body length and head circumference at birth differed by a few centimetres between groups of short and tall mothers. For boys, depending on their body length percentile, the values were from 3.5 to 2.5 cm [4].

In our research, tobacco smoking or exposure to tobacco smoke influenced only birth body length; no dependency regarding an infant's birth weight or head circumference was observed. When looking at the division into the gender of newborns, these impacts applied to boys only. In previous studies, the mother's smoking influenced her child's parameters, generally decreasing not only the birth weight [33] but also the head circumference and body length [34, 35] as well as the fat or the fat-free mass of an infant [36]. The lack of such results in our research can be explained by the low participation of smoking mothers, and there was no detailed analysis of the number of cigarettes smoked in pregnancy stages. It is worth noting that women frequently hide the fact that they use stimulants during pregnancy.

This study has several advantages. First, the analysis concerned not only body weight but also other birth parameters of the child. These parameters were interpreted in relation to a wide range of the mother's characteristics, her health behaviours, and weight gain, during pregnancy. It should also be emphasised

that an assessment of the variability of the newborn's features was made, not only for the entire population but also for the gender of the newborn.

The main limitation of our study is that there was only one hospital recruiting patients, which may not, therefore, give an overall picture of pregnant women for a given region. In addition, some of the variables evaluated in the study relied on the subjective assessment of those participating in the study, such as an assessment of their health behaviours.

Conclusions

Both a mother's weight before pregnancy and her weight gain during pregnancy, are a important factors influencing the further development of the child. The highest average somatic feature values in infants were noted in the group of women with weight gain during pregnancy above the recommended norms. Less dependency, though still statistically valid, was also found in relation to the mother's height and the newborn's somatic features. The infant's health condition is greatly correlated with the biological properties of the mother's organism, her correct weight, and her non-smoking status. Therefore, it is highly recommended for women in their reproductive period that activities be provided, promoting correct weight management, and that health hazards be avoided.

Conflict of interest

The authors declare no conflict of interest.

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