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Effects of pre-pregnancy BMI and gestational weight gain on pregnancy and neonatal outcomes in Poland

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Overweight and obesity are significant public health concerns, affecting pregnant women and potentially leading to numerous complications for both maternal and neonatal health. The aim of this study is to estimate how pre-pregnancy overweight and obesity, as well as gestational weight gain, influence pregnancy outcomes and neonatal health in Poland. The study material consisted of data from 2878 women aged 16–46 years from hospitals in Warsaw and Krosno. The analysis included data on the course of singleton pregnancies and the biological condition of the newborns, correlated with pre-pregnancy Body Mass Index (BMI) and gestational weight gain (GWG), which were compared to the standards set by the Institute of Medicine (IOM). Factor that significantly influences pre-pregnancy BMI and GWG is the number of pregnancies. For first-born women pre-pregnancy BMI was significantly lower than that of women giving birth for the second, third and subsequent times (ANOVA $p<0.0001$), at the same time, the increase in weight in this group was the greatest (ANOVA $p<0.0001$). The study found that pre-pregnancy BMI correlates more strongly with the occurrence of gestational diabetes than GWG above IOM recommendations (regression: $p<0.0001$, $R=0.112$ vs. $p<0.0001$, $R=0.104$). Analogous correlations were observed for the incidence of gestational hypertension and termination of pregnancy by caesarean section. Birth weight and length are significantly affected by both pre-pregnancy BMI and GWG but the effect of weight change is stronger (birth weight - pre-pregnancy BMI regression $p<0.0001$, $R=0.116$; GWG $p<0.0001$, $R=0.248$; birth length - pre-pregnancy BMI regression $p<0.0001$, $R=0.087$; GWG $p<0.0001$, $R=0.180$). An analogous relationship was observed for the presence of macrosomia. For APGAR scores, an inverse relationship was observed; while GWG did not show a significant relationship with the first minute score, perinatal neonatal status was significantly related to the mother's pre-pregnancy BMI (regression $p=0.0006$). Similarly, pre-pregnancy maternal BMI > 25 significantly increased the odds of perinatal injury and breastfeeding difficulties.

Keywords Overweight, Obesity, Pregnancy, Neonatal, Newborn outcomes

The World Health Organization (WHO) estimates that nearly 60% of the adult population and every third child are affected by overweight or obesity[1]. It indicates that the proportion of individuals struggling with these conditions has nearly tripled since 1975, allowing their prevalence to be classified as a pandemic[2,3]. This issue affects all nationalities, regardless of socioeconomic status[4], and importantly, both overweight and obesity are recognized as risk factors for numerous diseases[5–7]. Additionally, excessive body weight significantly impacts the overall quality of life of affected individuals[8] and increases their mortality rate[9].

The prevalence of overweight and obesity also concerns women of reproductive age. According to research presented by Stoś et al.[10], approximately 45% of women aged 18 to 49 in Poland struggle with excessive body weight. In the context of the increasingly advanced age at which women choose to have children—thereby increasing the age at which they have their first child—it is important to note that the proportion of women with overweight and obesity increases with age. Among women aged 18–29 years, the percentage of those

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with overweight and obesity is nearly 34%, while in the age group of 40–49 years, it rises to just over 63%[11]. Undoubtedly, this increase in the prevalence of overweight and obesity among women with age may result from a higher likelihood of postpartum weight retention from previous pregnancies. According to research, postpartum weight retention is a widespread issue and is often addressed in scientific studies and research[12,13].

Regardless of the underlying causes, overweight and obesity significantly impact reproductive capabilities in both women and men, substantially raising the risk of reduced or complete infertility[14,15]. Women with overweight and obesity experience earlier onset of menarche and nearly three times higher rates of menstrual irregularities[16] and anovulatory cycles[17]. Obesity may also diminish the fertilization potential of oocytes. As demonstrated by Machtinger et al.[18], oocytes from women with obesity are smaller and exhibit more spindle anomalies and chromosomal defects. Similarly, the effectiveness of in vitro fertilization is lower, which is attributed to the poorer quality of oocytes in women with obesity compared to those with normal body weight[19].

Pregnancies in women with overweight and obesity are more frequently accompanied by complications. Obese women experience a higher incidence of miscarriages[20,21] and are also more prone to gestational diabetes[22,23], preeclampsia, eclampsia, and hypertension[24–26]. Furthermore, labor in obese women is often more complicated, lasting longer, more frequently requiring induction (including the administration of oxytocin), and more often ending in cesarean delivery[27]. Postpartum hemorrhages are also more common in this group[28], and labor duration tends to be prolonged[29].

Maternal overweight and obesity, particularly obesity, also have a significant impact on the biological condition of newborns. Obese women are more likely to experience preterm births[30], although some studies suggest that a BMI above 50 predisposes to post-term deliveries[31]. Findings from several meta-analyses also indicate a relationship between maternal BMI and the occurrence of macrosomia in newborns, defined as a birth weight exceeding 4000 g, as well as large-for-gestational-age birth weight, characterized by a birth weight above the 90th percentile[32].

Similar associations concerning the risk of pregnancy complications, labor difficulties, and their impact on newborn outcomes have also been observed with excessive weight gain during pregnancy. Total GWG is calculated as the difference between the weight at the first prenatal visit and the weight at the last prenatal visit just prior to delivery. According to the recommendations of the Institute of Medicine (IOM)[33], the amount of weight women should gain during pregnancy is determined by specific ranges based on pre-pregnancy BMI. Similar to the pre-pregnancy BMI described above, excessive weight gain during pregnancy can adversely affect the occurrence of pregnancy complications and newborn outcomes[34,35]. Retention of excess weight after pregnancy is also significant, impacting the woman's health and potentially influencing the course of subsequent pregnancies[36,37].

Given the aforementioned issues, the objectives of this study were to examine how pre-pregnancy overweight and obesity affect pregnancy outcomes and newborn outcomes. Similarly, the study investigated how weight gain during pregnancy exceeding the standards set by the IOM influenced pregnancy outcomes and newborn outcomes.

Materials and methods

The research material consisted of data collected from medical records of women giving birth at St. Zofia's Hospital in Warsaw (1554 women) and the John Paul II Regional Hospital in Krosno (1324 women). The data collection was conducted with the authorization of the Ethics Committee of the John Paul II Podkarpackie Regional Hospital in Krosno, approved by the Cardinal Stefan Wyszynski University Ethics and Bioethics Committee for studies involving humans, and in accordance with the Declaration of Helsinki. All participants and/or their legal guardians provided informed consent, and all studies were conducted in full compliance with established standards.

The age of the women ranged from 16 to 46 years, with a mean of 30.6 years (+/− 4.84). The analysis included information on singleton pregnancies and pregnancies without recorded fetal genetic abnormalities. Table 1 presents the characteristics of the studied women regarding age, parity, pre-pregnancy body weight, and weight gain during pregnancy. The table also includes the results of significance testing comparing women giving birth in Warsaw and Krosno (using the Mann-Whitney test, $p < 0.05$, following the application of the Shapiro-Wilk test).

Despite the significant differences observed between women from Krosno and Warsaw, further analyses were conducted collectively for the entire group to provide the most average representation of the studied issue within the Polish population. This approach was also dictated by the relatively small number of women whose BMI classified them as obese.

	Warsaw (*n* = 1554)		**Krosno (*n* = 1324)**		
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	**Mann-Whitney test**
Age [years]	31.58 (4.84)	17.0–44.0	29.37 (5.30)	16.0–46.0	p < 0.001 (Z=-12.03)
Delivery	1.56 (0,74)	1.0–6.0	1.84 (0.98)	1.0–11.0	p < 0.001 (Z = 6.09)
Pre-pregnancy body weight [kg]	62.24 (10.88)	42.0-136.0	63.73 (12.32)	40.0-140.0	p = **0,005** (Z = 2.79)
Changes in body weight [kg]	14.57 (4.93)	1.0–43.0	13.47 (5.18)	-3.0-35.0	p < 0.001 (Z=-5.48)

Table 1. Characteristics of the studied women. Significant values are given in bold.

BMI was calculated as weight divided by height squared (kg/m^2). Height and weight were measured during the first prenatal visit and before delivery weight were measured again using standard measurement techniques[21]. The BMI categories were identified according to international standards[38]. Respondents were categorized into three BMI groups: normal-weight (≥ 18.5–24.9 kg/m^2), overweight (≥ 25.0–29.9 kg/m^2), and obese (≥ 30.0 kg/m^2). Weight change was calculated as the difference between pre-delivery and pre-pregnancy weight. The relationship between overweight and obesity among the participants and their parity was examined. For this purpose, the participants were divided into three groups: first-time mothers, second-time mothers, and those having their third or subsequent child. The analysis examined the relationship between overweight and obesity and infertility treatments, miscarriages (estimated as the difference between the number of pregnancies and births), pregnancy and perinatal complications (gestational diabetes, eclampsia, pregnancy-induced hypertension), PROM (Prelabor Rupture of Membranes), oligohydramnios, mode of delivery (cesarean section or vaginal delivery), perineal injuries during delivery (perineal lacerations), and incomplete placenta expulsion. Subsequently, the relationship between overweight and obesity in women and newborn outcomes was analyzed, including birth weight, birth length, APGAR score in first minute, the occurrence of macrosomia, perinatal injuries, and breastfeeding difficulties.

The gestational weight gain was also analyzed, which according to the 2009 IOM guidelines should not exceed 18 kg for underweight women, 16 kg for women with normal body weight, 11.5 kg for overweight women, and 9 kg for obese women. The women were divided into two groups based on GWG, about the 2009 IOM guidelines: those whose weight gain was below or within the norm, and those whose weight gain exceeded the IOM guidelines. This division was due to the small number of women whose body weight changed below IOM norms (207 in total).

Statistical analysis was performed using Statistica 13.0 software. To examine the relationships between variables, Spearman's rank correlation analysis, and linear and logistic regression were used, and to estimate the odds ratio, logistic regression analysis was applied. The significance of differences was analyzed using the Mann-Whitney tests (after applying the Shapiro-Wilk test) and ANOVA. For nominal variables, the χ^2 test was used for $p < 0.05$.

Results

The results are presented in Table 2. The applied Tukey post hoc test revealed that, in the case of pre-pregnancy weight, the mean values for women giving birth for the third and subsequent times were statistically significantly higher than for primiparas and those giving birth for the second time (first birth vs. third and subsequent: $p < 0.001$; second birth vs. third and subsequent: $p < 0.001$). No significant differences in mean pre-pregnancy weight were observed between women giving birth for the first and second times ($p = 0.1592$). For the mean pre-pregnancy BMI, the Tukey post hoc test revealed that the mean BMI values of women in subsequent pregnancies were statistically significantly higher (primiparas vs. second pregnancy: $p = 0.006$; second pregnancy vs. third and subsequent pregnancies, as well as first vs. third and subsequent pregnancies: $p < 0.001$).

Regarding the mean GWG, an opposite trend was observed: the average weight gain during the first pregnancy was significantly higher than during the second, third, and subsequent pregnancies (primiparas vs. second pregnancy: $p = 0.017$; second pregnancy vs. third and subsequent pregnancies, as well as first vs. third and subsequent pregnancies: $p < 0.001$). The conducted Spearman's rank correlation analysis confirmed that the relationships described above were statistically significant.

Next, the impact of overweight and obesity on women's reproductive abilities was examined. The analysis included infertility treatment among women and the occurrence of at least one miscarriage in their medical history. In the studied group, no statistically significant relationships were observed. However, in the case of infertility treatment, the percentage of women undergoing this procedure was highest in the obesity group. Regarding the history of miscarriage, no statistically significant relationship with pre-pregnancy BMI was found; however, it was noted that this percentage increased across successive BMI categories (Table 3).

Complications of pregnancy and childbirth

To evaluate the relationship between pre-pregnancy BMI, GWG, and the occurrence of selected pregnancy and childbirth complications, the first step was to estimate the proportion of women in each BMI category who gained weight by IOM recommendations (or less) versus those who exceeded these values. Among women with

	Body weight		**Pre-pregnancy BMI**		**Changes in body weight**	
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**
First birth ($n = 1434$)	62.05 (11.50)	42.0-140.0	22.39 (3.85)	14.54–49.60	14.51 (5.01)	−1.0-34.0
Secon birth ($n = 1060$)	62.90 (11.24)	40.0-117.0	22.78 (3.87)	15.62–44.58	13.95 (5.13)	−3.0-43.0
Third and subsequent births ($n = 384$)	66.22 (12.25)	42.0-126.0	24.04 (4.12)	16.73–41.52	12.71 (4.89)	1.0–29.0
ANOVA	p < **0,001** (F = 19.86)		p < **0,001** (F = 27.42)		p < **0,001** (F = 19.60)	
Spearman correlation	R = 0.1120; p < 0.001 (t(N-2) = 5.99)		R = 0.1400; p < 0.001 (t(N-2) = 7.58)		R = −0.1084; p < 0.001 (t(N-2) = −5.85)	

Table 2. Pre-pregnancy body weight, pre-pregnancy BMI and weight change during pregnancy and delivery order. Significant values are given in bold.

Factors	Per-pregnancy BMI	No *n*[%]	Yes *n*[%]
Infertility treatment	Normal weight ($n=2242$)	2213 [98.71]	29 [1.29]
	Overweight ($n=478$)	474 [99.16]	4 [0.84]
	Obesity ($n=158$)	155 [98.10]	3 [1.90]
χ^2	$p=0.5398$ ($\chi=1.2333$; df = 2)		
Miscarriages	Normal weight ($n=2242$)	1859 [82.92]	383 [17.08]
	Overweight ($n=478$)	396 [82.85]	82 [17.15]
	Obesity ($n=158$)	130 [82.28]	28 [17.72]
χ^2	$p=0.9789$ ($\chi=0.0426$; df = 2)		

Table 3. Infertility treatment and miscarriage occurrence.

	Pre-pregnancy BMI		
IOM standards	Normal weight ($n=2242$) [%]	Overweight ($n=478$) [%]	Obesity ($n=158$) [%]
At or below standard	1601 [71.41]	178 [37.24]	63 [39.87]
Above standard	641 [28.59]	300 [62.76]	95 [60.13]
χ^2	$p<$ **0.0001** ($\chi=241.93$; df = 2)		

Table 4. Weight changes in accordance with IOM, depending on pre-pregnancy BMI. Significant values are given in bold.

overweight and obesity, the proportion of individuals who gained more than the IOM-recommended values was more than twice as high compared to those with normal weight (Table 4).

In the next step, the relationship between pregnancy and childbirth complications, pre-pregnancy BMI, and gestational weight gain was analyzed. GWG was assessed based on whether weight gain during pregnancy was below, within, or above the ranges recommended by IOM standards (Table 5). Regarding the occurrence of gestational diabetes mellitus, the likelihood of developing this condition increased among overweight women and was the highest among obese women. The correlation coefficient (r) values indicate that pre-pregnancy BMI had a greater influence on the occurrence of gestational diabetes mellitus (GDM) than GWG. Adherence to IOM-recommended weight gain ranges did not appear to mitigate this risk. Interestingly, in the studied group, GDM was more frequently observed among women who gained weight by the IOM standards.

The prevalence of gestational hypertension depended on both pre-pregnancy BMI and gestational weight gain within the IOM recommendations. However, correlation coefficient (r) values indicate that pre-pregnancy BMI had a greater impact on the development of this condition.

A similar relationship was observed concerning the frequency of cesarean deliveries. Regarding PROM and oligohydramnios, these conditions were more frequently recorded among women with overweight and obesity; however, these differences were not statistically significant. Additionally, in the case of PROM, excessive GWG slightly increased its likelihood. Conversely, for oligohydramnios, no such association was observed. Interestingly, this condition was more frequently noted in women whose weight gain aligned with the IOM recommendations.

Perinatal complications during vaginal deliveries, such as perineal injuries and retained placenta, were more frequently observed in women with overweight and obesity. For perineal injuries, it was also shown that they occurred slightly more often in women whose gestational weight gain exceeded the values recommended by the IOM. Pre-pregnancy BMI had a somewhat greater influence on the occurrence of perineal injuries.

In contrast, no similar associations were recorded for eclampsia in the studied sample. This condition was slightly more common in the group of women with a BMI < 25 and those whose GWG was within the IOM recommendations. However, these results may be influenced by the overall low number of cases (a total of 19), which in turn could be attributed to the standards of care and early prevention.

Table 6 presents the mean values for birth weight and length, APGAR scores in the first minute of life, and the occurrence of selected newborn parameters based on the pre-pregnancy BMI of the studied women and whether their GWG was within the ranges recommended by the IOM standards.

For changes in measurable parameters, such as birth weight, length, and APGAR scores, the analysis accounted for the newborn's sex to explore potential differences between male and female infants. Newborns of both sexes born to women with overweight and obesity were heavier and longer than those born to women with a BMI < 25 (body mass above 3500 g vs. above 3300 g and body length above 55 cm vs. 54 cm, respectively; $p<0.0001$). For both birth weight and length, the r values indicate that GWG had a greater influence on these parameters than the mother's pre-pregnancy BMI.

In terms of GWG and pre-pregnancy BMI, both were found to slightly influence the birth weight of female newborns more strongly, but this difference was small and statistically insignificant. No similar associations were observed for APGAR scores.

The frequency of macrosomia increased in the group of overweight woman (newborns with macrosomia 14.44%) and obese women (newborns with macrosomia 17.72%), p for logistic regression is < 0.0001. Analogous relationships were observed for birth injuries (overweight woman newborns 4.60% and obese women newborns

		Pre-pregnancy BMI			**GWG according IOM**	
		Normal weight (*n* = 2242)	**Overweight (*n* = 478)**	**Obesity (*n* = 158)**	**At or below standard (*n* = 1842)**	**Above standard (*n* = 1036)**
Gestational diabetes mellitus	No n[%]	2092 [93.31]	432 [90.38]	134 [84.81]	1663 [90.28]	995 [96.04]
	Yes n[%]	150 [6.69]	46 [9.62]	24 [15.19]	179 [9.72]	41 [3.69]
	Odds ratio (95% CI)	1	1.48 (1.05–2.10)	2.43 (1.41–4.17)	-	
	χ^2	p = **0.0001** (χ = 18.28; df = 2)			p = **0.0001** (χ = 31.16; df = 1)	
	p, R, R^2 regression	p < **0.0001**; R = 0,112; R^2 = 0.012			p < **0.0001**; R = 0.104; R^2 = 0.011	
Gestational hypertension	No n[%]	2159 [96.30]	422 [88.28]	129 [81.65]	1795 [95.49]	951 [91.80]
	Yes n[%]	83 [3.70]	56 [11.72]	29 [18.35]	86 [4.51]	85 [8.20]
	Odds ratio (95% CI)	1	3.45 (2.42–4.92)	2.42 (1.92–3.04)	1	2.112 (1.716–2.863)
	χ^2	p < **0.0001** (χ = 93.68; df = 2)			p < **0.0001** (χ = 16.50; df = 1)	
	p, R, R^2 regression	p < **0.0001**; R = 0.180; R^2 = 0.032			p < **0.0001**; R = 0.076; R^2 = 0.006	
Caesarean section	No n[%]	1443 [64.42]	272 [57.14]	81 [51.27]	1190 [64.74]	606 [58.49]
	Yes n[%]	797 [35.58]	204 [42.86]	77 [48.73]	648 [35.26]	430 [41.51]
	Odds ratio (95% CI)	1	1.36 (1.11–1.66)	1.25 (1.08–1.43)	1	2.36 (1.88–2.97)
	χ^2	p = **0.0019** (χ = 10.63; df = 2)			p = **0.0009** (χ = 11.04; df = 1)	
	p, R, R^2 regression	p = **0.0001**; R = 0.075; R^2 = 0.006			*p* = 0.0012; *R* = 0.060 R^2 = 0.004	
PROM	No n[%]	2181 [97.28]	459 [96.03]	154 [97.47]	1789 [97.12]	1005 [97.01]
	Yes n[%]	61 [2.72]	19 [3.97]	4 [2.53]	53 [2.88]	91 [2.99]
	Odds ratio (95% CI)	1	1.48 (0.88–2.49)	0.91 (0.49–1.89)	1	1.04 (0.67–1.62)
	χ^2	*p* = 0.3206 (χ = 2.27; df = 2)			p = 0.8604 (χ = 0.0309; df = 1)	
	p, R, R^2 regression	p = 0.3208; R = 0. 008 R^2 = 0.001			p = 0.8604; *R* = 0.003 R^2 < 0.001	
Eclampsia	No n[%]	2227 [99.33]	475 [99.37]	157 [99.37]	1827 [99.19]	1032 [99.61]
	Yes n[%]	15 [0.67]	3 [0.63]	1 [0.63]	15 [0.81]	4 [0.39]
	Odds ratio (95% CI)	-			-	
	χ^2	*p* = 0.5398 (χ = 1.23; df = 2)			p = 0.1733 (χ = 1.85; df = 1)	
	p, R, R^2 regression	p = 0.9939; R = 0,002 R^2 < 0.001			p = 0.1734; R = 0.026 R^2 = 0.001	
Oligohydramnios	No n[%]	2220 [99.02]	473 [98.95]	154 [97.47]	1819 [98.75]	1028 [99.23]
	Yes n[%]	22 [0.98]	5 [1.05]	4 [2.53]	23 [1.25]	8 [0.77]
	Odds ratio (95% CI)	1	1.07 (0.39–2.91)	1.61 (0.94–2.78)	-	
	χ^2	p = 0.1887 (χ = 3.33; df = 2)			p = 0.2346 (χ = 1.1413; df = 1)	
	p, R, R^2 regression	p = 0.1889; R = 0.034 R^2 = 0.001			p = 0.2348; R = 0.022 R^2 = 0.001	
Natural birth						
		Normal weight (*n* = 1443)	Overweight (*n* = 272)	Obesity (*n* = 81)	At or below standard (*n* = 1842)	Above standard (*n* = 1036)
Perineal lacerations	No n[%]	784 [51.84]	126 [46.32]	39 [48.15]	623 [52.35]	290 [47.85]
	Yes n[%]	695 [48.16]	146 [53.68]	42 [51.85]	567 [47.65]	316 [52.15]
	Odds ratio (95% CI)	1	0.48 (0.387 – 0.06.1)	1.08 (0.86–1.35)	1	1.18 (0.98–1.46)
	χ^2	p = 0.2200 (χ = 3.03; df = 2)			p = 0.0714 (χ = 3.2506; df = 1)	
	p, R, R^2 regression	p = 0.2203; R = 0.041 R^2 = 0.001			p = 0.0715; R = 0.042 R^2 = 0.002	
Retained placenta	No n[%]	1374 [95.28]	255 [93.59]	75 [92.59]	1129 [94.87]	575 [95.04]
	Yes n[%]	68 [4.72]	18 [6.25]	6 [7.41]	61 [5.13]	30 [4.96]
	Odds ratio (95% CI)	1	0.75 (0.43–1.28)	1.27 (0.82–1.96)	-	
	χ^2	p = 0.3530 (χ = 2.08; df = 2)			p = 0.8786 (χ = 0.02; df = 1)	
	p, R, R^2 regression	p = 0.3533; R = 0.034 R^2 = 0.001			p = 0.8786; R = 0.004; R^2 < 0.001	

Table 5. Pre-pregnancy BMI and GWG in relation to pregnancy and perinatal complications. Significant values are given in bold.

			Pre-pregnancy BMI			GWG according IOM	
			Normal weight	**Overweight**	**Obesity**	**At or below standard (*n* = 1842)**	**Above standard (*n* = 1036)**
Body mass [g]	Male	Mean (+/-SD)	3453.2 (488.63)	3574.1 (474.3)	3551.3 (587.6)	3389.1 (486.9)	3630.6 (468.7)
		Range	1320.0-4860.0	1800.0-4830.0	1100.0-5310.0	1100.0-4800.0	2240.0-5310.0
	p, R and R^2 for regresion		p = 0.0009; R = 0.098; R^2 = 0.010			p < 0.0001; R = 0.236; R^2 = 0.056	
	Female	Mean (+/-SD)	3314.6 (480.23)	3462.3 (540.9)	2515.4 (509.8)	3257.3 (493.4)	3520.8 (453.5)
		Range	3314.6 (480.28)	500.0-5270.0	2300.0-5000.0	500.0-470.0	2130–5270
	p, R and R^2 for regresion		p < 0.0001; R = 0.137; R^2 = 0.017			p < 0.0001; R = 0.256; R^2 = 0.066	
	Total	Mean (+/-SD)	3383.9 (489.21)	3521.3 (509.8)	3532.9 (547.6)	3322.1 (494.5)	3579.8 (464.2)
		Range	800.0-4860.0	500.0-5270.0	1100.0-5310.0	500.0-4800.0	2130.0-5130.0
	p, R and R^2 for regresion		p < 0.0001; R = 0.1116; R^2 = 0.014			p < 0.0001; R = 0.248; R^2 = 0.061	
Body lenght [cm]	Male	Mean (+/-SD)	54.9 (2.81)	55.38 (2.73)	55.25 (3.50)	54.6 (2.87)	55.7 (2.60)
		Range	44.0–62.0	45.0–62.0	37.0–62.0	37.0–62.0	48.0–62.0)
	p, R and R^2 for regresion		p = 0.0407; R = 0.006; R^2 = 0.004			p < 0.0001; R = 0.186; R^2 = 0.034	
	Female	Mean (+/-SD)	54.1 (2.92)	54.87 (3.42)	54.80 (2.912)	53.6 (3.05)	54.95 (2.82)
		Range	35.0–63.0	25.0–63.0	46.0–65.0	25.0–63.0	35.0–65.0
	p, R and R^2 for regresion		**p = 0.0003**; R = 0.107; R^2 = 0.011			p < 0.0001; R = 0.171; R^2 = 0.029	
	Total	Mean (+/-SD)	54.48 (2.88)	55.1 (3.09)	55.02 (3,21)	54.2 (2.99)	55.3 (2.73)
		Range	35.0–63.0	25.0–63.0	37.0–65.0	25.0–63.0	35.0–65.0
	p, R and R^2 for regresion		p < 0.0001; R = 0.087; R^2 = 0.008			p < 0.0001; R = 0.180; R^2 = 0.032	
APGAR 1	Male	Mean (+/-SD)	9.78 (90.72)	9.75(0.92)	9.42 (1.52)	9.785 (0.77)	9.72 (0.90)
		Range	3.0–10.0	0.0–10.0	3.0–10.0	0.00–10.0	3.0–10.0
	p, R and R^2 for regresion		p = 0.0006; R = 0.101; R^2 = 0.010			p < 0.1374; R = 0.039; R^2 = 0.001	
	Female	Mean (+/-SD)	9.81 (0.76)	9.62 (1.27)	9.71 (0.66)	9.76 (0.86)	9.78 (0.84)
		Range	1.0–10.0	1.0–10.0	7.0–10.0	1.0–10.0	1.0–10.0
	p, R and R^2 for regresion		*p* = 0.0186; *R* = 0.074; R^2 = 0.005			p < 0.6223; R = 0.013; R^2 < 0.001	
	Total	Mean (+/-SD)	9.79 (0.74)	9.69 (1.11)	9.57 (1.16)	9.77 (0.82)	9.75 (0.88)
		Range	1.0–10.0	0.0–10.0	3.0–10.0	0.0–10.0	1.0–10.0
	p, R and R^2 for regresion		**p = 0.0006;** R = 0.072; R^2 = 0.005			*p* = 0.487; R = 0.013; R^2 < 0.001	
Other birth parameters							
			Normal weight (*n* = 2239)	Overweight (*n* = 478)	Obesity (*n* = 158)	At or below standard (*n* = 1836)	Above standard (*n* = 1036)
Makrosomia	No n[%]		2032 [90,80]	409 [85.56]	130 [82.28]	1171 [93.19]	858 [82.82]
	Yes n[%]		207 [9.21]	69 [14.44]	28 [17.72]	125 [6.81]	178 [17.18]
	Odds ratio (95% CI)		1	1.67 (1.24–2.23)	1.32 (1.17–1.82)	1	2.83 (2.23–3.62)
	χ^2		p = 0.0003 (χ = 20.87; df = 2)			p < 0.0001 (χ = 70.51; df = 1)	
	p, R, R^2 regresion		p < 0.0001; R = 0.085; R^2 = 0.007			p < 0.0001; R = 0.162; R^2 = 0.026	
Perinatal injuries	No n[%]		2181 [97.41]	456 [95.40]	150 [94.94]	1786 [97.28]	999 [96.43]
	Yes n[%]		58 [2.59]	22 [4.60]	8 [5.06]	50 [2.72]	37 [3.57]
	Odds ratio (95% CI)		1	1.82 (1.10–2.99)	1.32 (0.88–1.97)	1	1.32 (0.86–2.04)
	χ^2		p = 0.0371 (χ = 6.59; df = 2)			p = 0.1974 (χ = 1.66; df = 1)	
	p, R, R^2 regresion		p = 0.0371; R = 0.048; R^2 = 0.002			p = 0.1975; R = 0.024; R^2 = 0.001	
Breastfeeding difficulties	No n[%]		1812 [80.92]	359 [75.10]	116 [73.42]	1469 [80.02]	815 [78.67]
	Yes n[%]		427 [19.08]	119 [24.90]	42 [26.58]	367 [19.98]	221 [21.33]
	Odds ratio (95% CI)		1	5.99 (4.45–8.05)	5.27 (4.16–6.68)	1	0.92 (0.76–1.11))
	χ^2		p = 0.0023 (χ=12.18; df = 2)			p = 0.3685 (χ = 0.81; df = 1)	
	p, R, R^2 regresion		p = 0.0003 (χ=20.87; df = 2)			p = 0.3687; R = 0.011; R^2 < 0.001	

Table 6. Relationship between neonatal birth parameters and women's pre-pregnancy BMI and GWG at or above IOM recommendations. Significant values are given in bold.

5.06%; p for logistic regression is 0.0371) and also breastfeeding difficulties (overweight woman newborns 24.90% and obese women newborns 26.58%; p for logistic regression is 0.0023) .

. While gestational weight gain had a statistically significant impact on the occurrence of macrosomia, with the r values indicating its greater importance, it was not a contributing factor in the cases of birth injuries or feeding difficulties.

Discussion

In this study, it was found that both pre-pregnancy BMI and gestational weight gain, significantly influenced selected parameters of maternal health and newborn outcomes.

The literature contains numerous reports highlighting the increased pre-pregnancy weight of women having their second, third, or subsequent births compared to first-time mothers[39–41]. Some researchers suggest that the increasing weight of women with subsequent pregnancies is a result of postpartum weight retention. However, many authors believe that factors such as the age of menarche and the short interval between menarche and the first childbirth are equally important. The findings indicate that these factors may also contribute to the development of overweight status following pregnancy[18,42].

In the present study, the average GWG during the first pregnancy was significantly higher than in the second, third, and subsequent pregnancies. Heery et al.[43] observed a similar trend. Many women indulge in snacking and satisfying food cravings during pregnancy. At the same time, they give up physical activity out of concern for potential risks to the fetus. However, during subsequent pregnancies, women were more apprehensive about gaining excessive weight again, as they had faced challenges losing weight after previous deliveries. At the same time, most women did not consider that having previously delivered a macrosomic newborn could influence their lifestyle choices.

In the studied group of women, no statistically significant relationship was found between undergoing infertility treatment and obesity. However, the highest percentage of women undergoing such procedures was observed in the overweight and obese groups. Similar findings have been reported by many authors. It is noted that individuals with obesity respond less effectively to ovulation induction and require higher doses of gonadotropins. Additionally, it is believed that overweight and obesity may affect oocyte activity, endometrial receptivity, fertilization rates, and the number of embryos obtained[44–46]. Some researchers also suggest that even significant weight loss in obese women before in vitro fertilization (IVF) procedures did not improve live birth rates[47]. George et al.[48] reported that IVF outcomes and newborn parameters in overweight and obese individuals were similar to those in women with normal body weight. However, the study emphasized the critical role of specialized obstetric and gynecological care in qualified hospitals. On the other hand, Zheng et al.[49] observed no association between BMI and the likelihood of achieving pregnancy or delivering a live baby, though the risk of miscarriage was higher.

In the present study, no significant relationship was found between higher pre-pregnancy BMI and miscarriages. However, the percentage of miscarriages increased across successive BMI categories. It is widely believed that women with overweight or obesity face a significantly higher risk of miscarriage. This applies both to women who conceived naturally and those who underwent IVF[50]. Additionally, it is noted that individuals struggling with excessive body weight experience recurrent miscarriages more frequently compared to those with normal pre-pregnancy weight[51]. Some researchers also suggest that the increased risk of miscarriage is observed in obese women, but not in those who are merely overweight[52]. Researchers emphasize that maintaining a healthy pre-pregnancy BMI is crucial in preventing miscarriages[53].

The results of the conducted study suggest that in the case of women with overweight and obesity, more than twice as many participants increased their body weight beyond the levels recommended by IOM guidelines. A meta-analysis conducted in 2009 demonstrated that weight gain exceeding IOM recommendations occurred in 27.8% of cases, and this trend has continued to grow. In the United States, weight gain below, within, and above IOM guidelines has been observed in 5%, 13%, and 80% of overweight women, respectively, as well as in 17%, 13%, and 70% of obese women[34,54]. Interestingly, findings from Poland in 2019 suggest that mean pregnancy weight gain among overweight and obese women is lower than that of women with normal body weight[55].

The present study demonstrated that in women with overweight and obesity, the risk of developing gestational diabetes mellitus during pregnancy increased, with pre-pregnancy BMI having a greater impact on the occurrence of GDM. However, GDM was more frequently observed in women who gained weight by IOM guidelines. Najafi et al.[56] reported that the risk of developing GDM in the underweight/normal weight group was over 10%, while in the group of women with overweight and obesity, it was 23%. Other studies confirm that a higher risk of developing GDM is associated with higher pre-pregnancy BMI values and excessive weight gain during pregnancy[57]. Research findings also suggest that maintaining a stable body weight before pregnancy is extremely important, even in the five years before conception. Women who gained 2.3–10 kg per year before pregnancy had an increased risk of developing GDM compared to those with stable body weight[58].

The occurrence of gestational hypertension was also correlated with pre-pregnancy BMI values. Other researchers have estimated that women who were overweight or obese before pregnancy, as well as those whose GWG exceeded the recommendations set by the IOM, were more likely to experience hypertension during pregnancy compared to their normal-weight counterparts[59,60]. Slightly different results were obtained by Savitri et al.[61]. According to their findings, pre-pregnancy BMI values determined the blood pressure levels of pregnant women and were correlated with more frequent occurrences of gestational hypertension. However, gestational weight gain did not influence the increased prevalence of this pregnancy complication.

A similar relationship was observed in the current study regarding the performance of cesarean sections. Researchers investigating cesarean sections have noted that women with pre-pregnancy obesity, as well as those who experience excessive gestational weight gain during pregnancy, are more likely to undergo a cesarean delivery. It has also been observed that the risk of cesarean section increases in women who had a normal pre-pregnancy weight but gained more weight during pregnancy than recommended by the IOM guidelines[62]. Other studies conducted in Poland also indicate similar trends[63].

The occurrence of PROM and oligohydramnios was more frequently recorded in women with overweight and obesity; however, these differences were not statistically significant. Similarly, the observation of eclampsia was not associated with overweight or obesity. Spontaneous preterm births with PROM were more frequently observed in overweight women who experienced greater gestational weight gain than recommended by the

IOM guidelines. It was also noted that lower GWG during pregnancy was a significant factor in reducing the likelihood of preterm delivery[64]. In the studies by Feng and Huang[65] and Blitz et al.[66], similar results were obtained for oligohydramnios - this condition was not significantly associated with overweight or obesity. However, the article by Yayla Abide et al.[67] reported that among women with excessive GWG, the rate of oligohydramnios was higher than in women who gained weight within the recommended range. Findings from other authors regarding eclampsia differed from those obtained in the present study. It was noted that women with pre-pregnancy overweight or obesity, as well as excessive GWG, were more likely to develop preeclampsia compared to their normal-weight counterparts[68].

Perineal lacerations and retained placenta were more frequently observed among overweight and obese women in Poland compared to women with normal body weight. A significant association was identified both in cases where GWG exceeded the values recommended by the IOM and among women with elevated pre-pregnancy BMI. Other authors have reached similar conclusions[69]; however, Gallagher et al.[70] did not observe such associations.

It is noted that the majority of the cited research findings are consistent. Women with pre-pregnancy BMI values above the normal range were more likely to experience health issues during pregnancy as well as more frequent labor complications.

"It is also important to address the condition of newborns. Newborns of both sexes born to women with overweight and obesity were heavier and longer compared to those born to women with a BMI < 25. These findings align with the data reported by other researchers[71]. This may also influence women's experiences during pregnancy and childbirth, for example, the occurrence of perineal lacerations[72]. The gestational weight gain had a greater impact on shaping the above-mentioned birth parameters of the newborns than the pre-pregnancy BMI of the mothers. Similar relationships have also been observed in data published by other researchers. This represents a significant public health issue, as children with macrosomia have a considerably increased likelihood of developing overweight and obesity later in life[73,74].

In the case of APGAR scores, no influence of either pre-pregnancy BMI or excessive gestational weight gain during pregnancy was observed. Different results were reported in studies from the US. In pregnant women with excessive GWG during pregnancy versus those without condition, APGAR was significantly lower compared to their normal-weight counterparts. This may be due to previously mentioned findings suggesting that women with excessive GWG during pregnancy experience more disturbances during both pregnancy and delivery[75].

Studies conducted in Poland suggest that the likelihood of experiencing breastfeeding difficulties increased among women with overweight and obesity. However, no problems with breastfeeding were noted in the case of excessive GWG. Similar results were observed among women in the US and China, where earlier-than-standard breastfeeding cessation occurred more frequently[76,77]. Many studies also suggest that increased pre-pregnancy BMI was associated with decreased breastfeeding initiation[78–80]. Although this is a common phenomenon, its mechanism remains unclear. It may result from the influence of increased body fat on prolactin and oxytocin, leading to delayed lactation. It is also believed that other health consequences of excessive body weight during pregnancy, such as gestational diabetes, gestational hypertension, and cesarean delivery, may contribute to the lack of breastfeeding initiation[81–83].

The increasingly common prevalence of overweight and obesity, combined with the observed steady rise in the age at which women have their first child, represents a global issue. This combination constitutes a growing problem, carrying not only financial consequences related to the care of pregnant women with excessive body weight and the health outcomes of their offspring but also serious demographic implications.

The present study has several limitations. The first is the relatively small study group, which resulted from restrictions in the medical record systems at hospitals. Pre-pregnancy body weight was not recorded for all patients, which prevented the collection of information on gestational weight gain. The second limitation is the combination of data from hospitals in Warsaw, the largest city in Poland, with data from a regional hospital in Podkarpacie region. However, combining both datasets provided a more comprehensive view of pregnant women and newborn outcomes in Poland. The sample lacked women with morbid obesity (BMI above 40). Additionally, episiotomies and perineal lacerations were combined into a single factor -perineal injuries during delivery. This was due to the small sample size in individual groups when these factors were considered separately. Therefore, the authors of the study are concerned that the study group may not be fully representative. A low percentage of cases with eclampsia was also observed, which may, however, be attributable to good cardiac care and regular monthly visits by the patients.

Data availability

The data base of the mothers and the children information have not been made public to ensure the privacy of study participants, and are stored by the John Paul II Province Hospital in Krosno and in St. Zofia's Hospital in Warsaw and are available from the corresponding author on reasonable request. Correspondence and requests for materials should be addressed to J.N.-D.

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Author contributions

Conceptualization: JMD, JND, Design of the work: JMD, JND, MK, Methodology: JMD Formal analysis: JMD, Interpretation of the data: JMD, Acquisition: KK, DS, BB, Writing – draft version: JMD, JND, Writing – review and editing: JMD, JND, KK, VB, MK, DS, BB. All authors approved the submitted version.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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