Hrana u zdravlju i bolesti, znanstveno-stručni časopis za nutricionizam i dijetetiku (2026) 15 (2) 51-59
Food in Health and Disease, scientific-professional journal of nutrition and dietetics (2026) 15 (2) 51-59

ASSOCIATION OF BODY MASS INDEX AT THE END OF PREGNANCY AND GESTATIONAL WEIGHT GAIN WITH MODE OF DELIVERY AND DELIVERY COMPLICATIONS

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original scientific paper

Summary

Overweight in pregnancy and excessive gestational weight gain are associated with more frequent cesarean delivery and delivery complications. This retrospective observational study examined the association of body mass index at the end of pregnancy and gestational weight gain with mode of delivery and with at least one recorded delivery complication (birth canal injury, shoulder dystocia, or uterine inertia). It included 1070 deliveries at the General County Hospital Požega (2023–2025). Group differences were assessed using the Mann–Whitney U test, the association between the two exposures using Spearman's correlation coefficient, and associations with outcomes using binary logistic regression adjusted for maternal age, parity, and gestational age. Cesarean delivery was performed in 323 deliveries (30.2%), and at least one complication was recorded in 390 (36.4%). The median body mass index at the end of pregnancy was 28.60 kg/m², and the median gestational weight gain was 12 kg. Body mass index at the end of pregnancy was higher in cesarean deliveries ($p < 0.001$) and remained associated with cesarean delivery in the multivariable model ($p < 0.001$). Gestational weight gain was not associated with mode of delivery in the multivariable model ($p = 0.943$). Weight gain was greater in women with complications in the bivariate analysis ($p = 0.004$), but after adjustment neither weight gain nor body mass index was significantly associated with complications, whereas higher parity was associated with lower odds of complications. The results indicate an association between higher body mass index at the end of pregnancy and higher odds of cesarean delivery. Because the study was observational and the models showed imperfect calibration, the results do not allow reliable individual-level prediction. Body mass index at the end of pregnancy may be considered one of the factors in assessing the risk of cesarean delivery rather than a stand-alone indicator.

Keywords: cesarean delivery, gestational weight gain, body mass index, delivery complications, mode of delivery

Introduction

Overweight and obesity in women of reproductive age are among the most important public health problems in contemporary obstetrics. Belošević (2022) cites Eurostat data according to which, in 2019, Croatia was among the European Union countries with the highest proportion of adults with overweight or obesity. Nutritional status is most commonly assessed using the body mass index (BMI), the ratio of body weight in kilograms to the square of body height in meters. BMI is a simple screening method, but it does not distinguish between fat, muscle, and bone tissue (Belošević, 2022). In pregnancy, its use is further limited by changes in body weight during gestation and by the lack of generally accepted cut-off values for late pregnancy (Misan et al., 2022).

Higher maternal BMI is associated with gestational diabetes, hypertensive disorders, labor induction, cesarean delivery, and postpartum hemorrhage (Zhang et al., 2024), as well as with fetal macrosomia (Barišić, 2015; Bouvier et al., 2019). Another important and potentially modifiable factor is gestational weight gain (GWG) (Bilić, 2026). The 2009 recommendations of the US Institute of Medicine (IOM) define the desirable total weight gain according to pre-pregnancy BMI: 12.5–18 kg for underweight women, 11.5–16 kg for women with normal weight, 7–11.5 kg for women with overweight, and 5–9 kg for women with obesity (Bouvier et al., 2019; Jaworowski et al., 2025).

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Nevertheless, in a meta-analysis of more than 1.6 million women, 45% of pregnant women gained weight above the recommendations and 23% below them (Goldstein et al., 2025). In a sample from Split, 51.9% of pregnant women exceeded the recommended GWG (Bilić, 2026).

The association of pre-pregnancy or early-pregnancy BMI with cesarean delivery has been described in a meta-analysis of 83 studies including almost two million women (Zhang et al., 2024) and in large cohorts (Bouvier et al., 2019; Dalbye et al., 2021), including a retrospective analysis of almost 15 000 deliveries at the Clinical Hospital Center Rijeka (Barišić, 2015). Data on GWG are less consistent. Greater GWG, defined according to the IOM recommendations or as a z-score standardized for gestational age, has been associated with higher odds of cesarean delivery in a meta-analysis and large cohorts (Kominiarek et al., 2018; Xu et al., 2021; Goldstein et al., 2025). In some studies, no association was observed after adjustment or in smaller samples (Omani-Samani et al., 2018; Lackovic et al., 2024; Erbey et al., 2026). Findings on delivery complications are even more heterogeneous and depend on the type of complication and on the study (Kominiarek et al., 2018; Dalbye et al., 2021; Choi et al., 2022).

Some of these differences may arise from methodology. Most studies analyze pre-pregnancy BMI, often calculated from self-reported body weight (Swank et al., 2014; Kominiarek et al., 2018), and GWG is defined in different ways (Xu et al., 2021). BMI measured at the end of pregnancy, for example on admission to the delivery ward, is a readily available clinical measure, but its association with delivery outcomes has been studied less often (Misan et al., 2022; Jaworowski et al., 2025; Erbey et al., 2026), particularly together with GWG and with both variables analyzed as continuous.

The aim of this study was to examine the association of end-of-pregnancy BMI and GWG with mode of delivery (cesarean versus vaginal delivery) and with the occurrence of at least one recorded delivery complication, adjusted for maternal age, parity, and gestational age, and to describe the prevalence of hypertension and gestational diabetes in the study sample.

Materials and methods

Participants and data

This retrospective observational study was based on the medical records of women who gave birth at the General County Hospital Požega from 2023 to 2025. Women with a singleton pregnancy and a known delivery outcome were included. Women with unavailable or incomplete medical records on the course of pregnancy and delivery, women with a multiple pregnancy, and pregnancies ending in stillbirth or termination before delivery were excluded. All deliveries during the study period that met the inclusion criteria were included. Data on end-of-pregnancy BMI and on GWG were missing for one delivery, which was retained in the descriptive analysis but excluded from the regression models.

Data were collected on maternal age, parity, gestational age at delivery, GWG, end-of-pregnancy BMI, gestational diabetes and hypertension in pregnancy, mode of delivery and delivery complications, as well as on neonatal birth weight and Apgar scores at 1 and 5 minutes.

Definitions of variables

GWG was calculated as the difference between body weight at the end and at the beginning of pregnancy (Eq. 1):

$$\text{GWG (kg)} = \text{body weight at the end of pregnancy (kg)} - \text{body weight at the beginning of pregnancy (kg)} \quad (1)$$

Body weight at the end of pregnancy was obtained from the measurement on admission to the delivery ward, and body weight at the beginning of pregnancy from the record of the first visit to the primary care gynecologist. End-of-pregnancy BMI was calculated as the ratio of body weight measured on admission to the delivery ward to the square of body height (Eq. 2):

$$\text{BMI (kg/m}^2\text{)} = \text{body weight (kg)} / [\text{body height (m)}]^2 \quad (2)$$

The composite outcome “at least one recorded delivery complication” comprised first- or second-degree perineal tear, cervical or vaginal tear, shoulder dystocia, and primary or secondary uterine inertia. The outcome was considered present if at least one of these complications was recorded in the medical records.

Ethics

The study was approved by the Ethics Committee of the General County Hospital Požega (reference number 02-7/3-3/2-6-2026, dated August 21, 2026). Because this was a retrospective analysis of existing medical records, informed consent was not obtained from the women.

Statistical methods

Categorical data were presented as absolute and relative frequencies, n (%). Continuous variables were presented as medians and interquartile ranges, Mdn (Q1–Q3), because the key continuous variables deviated from a normal distribution according to the Shapiro–Wilk test. Differences in continuous variables between two independent groups were assessed using the Mann–Whitney U test. The association between BMI and GWG was assessed using Spearman's correlation coefficient. Associations between continuous predictors and binary outcomes were examined using binary logistic regression. Regression results were reported as odds ratios (OR), 95% confidence intervals (95% CI), and p-values. Model fit was assessed using the likelihood-ratio test, Nagelkerke's pseudo-R^2, the area under the receiver operating characteristic (ROC) curve (AUC), and the Hosmer–Lemeshow test. The level of statistical significance was set at $p < 0.05$.

One record with missing data on BMI and GWG was excluded from the regression models, so both models were fitted on 1069 deliveries. Parity was coded as the ordinal number of the index delivery (1 = first delivery, 2 = second delivery, etc.) rather than as the number of previous deliveries and was included in the models as a numerical variable, so the OR refers to an increase of one delivery. Multicollinearity was assessed using variance inflation factors (VIF). Linearity of the association between continuous predictors and the logit of the outcome was assessed by comparing linear terms with cubic B-splines with four degrees of freedom using the likelihood-ratio test. For variables showing departures from linearity, sensitivity analyses were performed in which these variables were modeled flexibly. In the complications model, the analysis was additionally repeated after excluding GWG values outside the 1st–99th percentile range. Details are provided in Tables 1 and 2.

Statistical analysis was performed in the RStudio Desktop environment, version 2026.09.0+174 (Posit Software, PBC, Boston, Massachusetts, USA), using the R programming language, version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria). The dplyr, tidyr, stringr, and stringi packages were used for data processing and organization, and the broom, car, ResourceSelection, and pROC packages for statistical modeling, presentation of estimates, and regression diagnostics.

Table 1. Basic sample characteristics and analyzed outcomes (n = 1070)

Characteristic	**Mdn (Q1–Q3) or n (%)**
Maternal age / years	30 (27–33)
Parity (ordinal number of delivery)	2 (1–2)
Gestational age / weeks	39 (38–40)
BMI at the end of pregnancy / (kg/m²)	28.60 (25.86–31.51)
Gestational weight gain / kg	12 (9–15)
Cesarean delivery	323 (30.2)
Any recorded delivery complication	390 (36.4)
Hypertension	35 (3.3)
Gestational diabetes	12 (1.1)

Note: BMI – body mass index; Mdn – median; Q1 – first quartile; Q3 – third quartile; n – number of women; % – percentage. Data on BMI and gestational weight gain were missing for one delivery. Delivery complications: first- or second-degree perineal tear, cervical or vaginal tear, shoulder dystocia, primary or secondary uterine inertia.

Table 2. BMI and gestational weight gain according to delivery outcomes

Outcome	**Variable**	**Without outcome, Mdn (Q1–Q3)**	**With outcome, Mdn (Q1–Q3)**	**p**
Cesarean delivery	BMI / (kg/m²)	28.08 (25.43–30.82)	29.76 (26.89–33.37)	< 0.001
Cesarean delivery	Weight gain / kg	12 (9–15)	12 (9–15)	0.656
Any complication	BMI / (kg/m²)	28.39 (25.71–31.25)	28.91 (26.03–31.83)	0.072
Any complication	Weight gain / kg	12 (9–15)	13 (10–15)	0.004

Note: BMI – body mass index; Mdn – median; Q1 – first quartile; Q3 – third quartile; p – level of statistical significance (Mann–Whitney U test).

Results and discussion

Sample characteristics and bivariate analyses

Of the 1070 deliveries, 323 (30.2%) were cesarean deliveries, and at least one complication was recorded in 390 deliveries (36.4%). The median end-of-pregnancy BMI was 28.60 kg/m², and the median GWG was 12 kg. Hypertension was recorded in 35 women (3.3%) and gestational diabetes in 12 women (1.1%). Other sample characteristics are shown in Table 1.

In bivariate analyses, BMI was significantly higher in cesarean deliveries ($p < 0.001$), whereas GWG did not differ by mode of delivery ($p = 0.656$). BMI did not differ significantly according to the occurrence of delivery complications ($p = 0.072$), whereas GWG was greater in women with complications ($p = 0.004$) (Table 2).

End-of-pregnancy BMI and GWG showed a weak positive correlation (Spearman's $\rho = 0.136$; $p < 0.001$) (Table 3), which does not indicate a multicollinearity problem when both are entered simultaneously in the regression models.

Table 3. Correlation between BMI at the end of pregnancy and gestational weight gain

Variables	ρ	p
BMI at the end of pregnancy – gestational weight gain	0.136	< 0.001

Note: BMI – body mass index; ρ – Spearman's correlation coefficient; p – level of statistical significance.

Multivariable analysis: cesarean delivery

In the multivariable model for cesarean delivery, with BMI and GWG entered simultaneously and adjustment for maternal age, parity, and gestational age, higher BMI was associated with higher odds of cesarean delivery (OR = 1.09; 95% CI 1.06–1.13; $p < 0.001$), whereas GWG was not significantly associated with the outcome ($p = 0.943$). Older maternal age was associated with higher odds, and higher parity and longer gestational age with lower odds of cesarean delivery. The model was statistically significant, but the Hosmer–Lemeshow test ($p = 0.039$) indicated a departure from adequate calibration (Table 4). The model included 1069 deliveries (322 cesarean deliveries), and VIF values ranged from 1.018 to 1.139. Departures from linearity were identified for parity ($p = 0.013$) and gestational age ($p = 0.002$), but not for BMI ($p = 0.219$) or GWG ($p = 0.223$). When parity and gestational age were modeled flexibly, BMI remained associated with cesarean delivery (OR = 1.09; 95% CI 1.06–1.12; $p < 0.001$) (Tables 1 and 2).

Table 4. Multivariable logistic regression for cesarean delivery (n = 1069)

Variable	OR	95 % CI	p
BMI (per 1 kg/m²)	1.09	1.06–1.13	< 0.001
Gestational weight gain (per 1 kg)	1.00	0.97–1.03	0.943
Maternal age (per 1 year)	1.04	1.01–1.07	0.010
Parity (per 1 delivery)	0.63	0.54–0.74	< 0.001
Gestational age (per 1 week)	0.81	0.73–0.90	< 0.001

Note: BMI – body mass index; OR – odds ratio; 95 % CI – 95 % confidence interval; p – level of statistical significance; AUC – area under the ROC curve. Outcome: cesarean delivery (yes = 1); 322 deliveries with the outcome. Parity was coded as the ordinal number of the index delivery. $\chi^2(5) = 88.33$, $p < 0.001$; Nagelkerke's $R^2 = 0.112$; AUC = 0.676; Hosmer–Lemeshow test $p = 0.039$.

Multivariable analysis: delivery complications

In the model for any recorded delivery complication, neither BMI (OR = 1.02; 95% CI 0.99–1.05; $p = 0.129$) nor GWG (OR = 1.01; 95% CI 0.99–1.04; $p = 0.287$) was significantly associated with the outcome, whereas higher parity was associated with lower odds of complications (OR = 0.62; 95% CI 0.54–0.72; $p < 0.001$). The model was statistically significant, but the Hosmer–Lemeshow test ($p = 0.002$) indicated poorer calibration (Table 5).

The model included 1069 deliveries (389 with at least one complication). Departures from linearity were identified for GWG ($p = 0.025$), parity ($p < 0.001$), and gestational age ($p = 0.002$), but not for BMI ($p = 0.208$), which was not significantly associated with complications in the flexible model either (OR = 1.02; 95% CI 0.99–1.05; $p = 0.123$). The nonlinear association between GWG and complications was statistically significant in the exploratory analysis ($p = 0.040$), but not after excluding GWG values outside the 1st–99th percentile range ($p = 0.118$). This finding is sensitive to extreme values and cannot be regarded as a reliable indicator of an independent association (Tables 1 and 2).

Table 5. Multivariable logistic regression for delivery complications (n = 1069)

Variable	OR	95 % CI	p
BMI (per 1 kg/m²)	1.02	0.99–1.05	0.129
Gestational weight gain (per 1 kg)	1.01	0.99–1.04	0.287
Maternal age (per 1 year)	1.01	0.98–1.04	0.379
Parity (per 1 delivery)	0.62	0.54–0.72	< 0.001
Gestational age (per 1 week)	1.00	0.91–1.11	0.948

Note: BMI – body mass index; OR – odds ratio; 95 % CI – 95 % confidence interval; p – level of statistical significance; AUC – area under the ROC curve. Outcome: any recorded delivery complication (yes = 1; components listed in the note to Table 1); 389 deliveries with the outcome. Parity was coded as in Table 4. $\chi^2(5) = 56.18$, $p < 0.001$; Nagelkerke's $R^2 = 0.070$; AUC = 0.662; Hosmer–Lemeshow test p = 0.002.

BMI at the end of pregnancy and cesarean delivery

The main finding of this study is the association of higher end-of-pregnancy BMI with higher odds of cesarean delivery, which persisted after adjustment for GWG, maternal age, parity, and gestational age. This finding is consistent with previous studies of BMI measured at delivery. In a Polish study of 2104 women, obesity before delivery was associated with higher odds of cesarean delivery compared with normal weight (adjusted OR 1.63) (Misan et al., 2022), and in a Turkish cohort of 501 induced pregnancies, the odds of cesarean delivery were approximately 50% higher with each higher category of BMI measured on admission (Erbey et al., 2026). Because BMI increases by several units during pregnancy (Morais et al., 2018), BMI categories at delivery are not equivalent to pre-pregnancy categories, which makes direct comparison difficult.

The same direction of association has been described for pre-pregnancy or early-pregnancy BMI. In the meta-analysis by Zhang et al. (2024), the odds of cesarean delivery were 1.44 times higher in women with overweight and 2.23 times higher in women with obesity, and similar gradients have been described in studies from Norway, Canada, Korea, and Nigeria, and at the Clinical Hospital Center Rijeka (Barišić, 2015; Bouvier et al., 2019; Dalbye et al., 2021; Senbanjo et al., 2021; Choi et al., 2022). The estimate from the present study, approximately 9% higher odds per 1 kg/m² of BMI, is close to the estimate of 10 to 12 % per 1 kg/m² of pre-pregnancy BMI in a Polish study (Jaworowski et al., 2025). In smaller samples or samples with few women with obesity, an association was not always observed (Aji et al., 2022; Long et al., 2025; Bilić, 2026), which may reflect low statistical power and unstable estimates when BMI is categorized rather than necessarily a different direction of association.

Possible explanations for this association proposed in the literature include prolonged labor (Yeşilçiçek Çalik et al., 2018), poorer cervical ripening, more frequent failed induction, and weaker myometrial contractility (Erbey et al., 2026), narrowing of the birth canal by excess soft tissue (Belošević, 2022), and fetal macrosomia (Misan et al., 2022). Because data on indications for cesarean delivery and on labor induction were not available, and neonatal birth weight was not included in the models, it cannot be assessed which of these mechanisms may have been relevant in this sample.

Because BMI and GWG were included simultaneously in the model, the estimate for BMI refers to women with the same GWG and may partly reflect pre-pregnancy nutritional status, as in studies in which baseline nutritional status was more strongly associated with cesarean delivery than GWG was (Choi et al., 2022; Erbey et al., 2026). Without data on pre-pregnancy BMI, this cannot be verified directly in this sample, and end-of-pregnancy BMI should therefore not be interpreted as a direct measure of pre-pregnancy nutritional status.

Gestational weight gain and mode of delivery

The absence of an association between GWG and mode of delivery is consistent with the findings of an Iranian study in which no association was found after adjustment for confounders (Omani-Samani et al., 2018), a Turkish cohort of induced deliveries (Erbey et al., 2026), and smaller samples from Serbia, Nigeria, and Indonesia (Senbanjo et al., 2021; Aji et al., 2022; Lackovic et al., 2024). In a Polish study, continuous GWG was only borderline significant (OR 1.05 per 1 kg; 95 % CI 1.00–1.10) (Jaworowski et al., 2025), and the upper limit of the confidence interval in the present study (1.03 per 1 kg) does not exclude a weak association either.

In contrast, in the meta-analysis by Goldstein et al. (2025), GWG above the IOM recommendations was associated with higher odds (OR 1.37) and GWG below the recommendations with lower odds of cesarean delivery (OR 0.90). An association has also been described in large cohorts from the USA, Sweden, Canada, Korea, and China (Kominiarek et al., 2018; Bouvier et al., 2019; Dude et al., 2021; Xu et al.,

2021; Choi et al., 2022; Long et al., 2025). In a Californian cohort of more than 430 000 women, the odds were substantially higher only when BMI increased by more than 10 kg/m² (Swank et al., 2014), and the odds ratio of 2.71 in a Polish national study was unadjusted and based on self-reported body weight (Goławski et al., 2023).

Several explanations for these differences are possible. The cited studies mostly classified GWG according to the IOM recommendations, which depend on pre-pregnancy BMI, or standardized it for gestational age (Kominiarek et al., 2018; Xu et al., 2021; Goldstein et al., 2025), whereas absolute GWG was analyzed in the present study. Women with higher baseline body weight put on fewer kilograms on average (Bodnar et al., 2010; Erbey et al., 2026) but more often exceed the recommendations (Aji et al., 2022; Lackovic et al., 2024), so the same GWG in kilograms has a different meaning in women with different nutritional status, and the IOM recommendations may not be equally appropriate for all populations (Sun et al., 2021). In large studies, the association is moderate and partly limited to extreme values of GWG (Swank et al., 2014), and a sample of 1069 deliveries has limited statistical power to detect such effects. With end-of-pregnancy BMI included simultaneously in the model, part of the association between GWG and the outcome may be transferred to BMI, but no difference in GWG was found in the bivariate analysis either. Finally, some cesarean deliveries may result from indications unrelated to body weight, such as fetal malpresentation (Kapinos et al., 2017), and previous cesarean delivery is an important confounder in multiparous women (Dude et al., 2021).

Delivery complications

The association of greater GWG with complications observed in the bivariate analysis did not remain significant after adjustment, and higher parity was associated with lower odds of complications. This may indicate a confounding effect of parity, because women with greater GWG in the Californian and Swedish cohorts were more often nulliparous (Swank et al., 2014; Xu et al., 2021), although in a Turkish study greater GWG was observed in multiparous women (Yeşilçiçek Çalik et al., 2018).

The composite outcome in this study comprised birth canal injuries (first- or second-degree perineal tear, cervical or vaginal tear), shoulder dystocia, and uterine inertia, i.e., events with different underlying mechanisms. The absence of an association of BMI and GWG with such an outcome is consistent with findings from a Korean cohort of 3454 pregnant women, in which neither obesity nor excessive GWG was significantly associated with a composite outcome that included, among other events, birth canal injuries and shoulder dystocia (Choi et al., 2022), and with a Polish study in which the frequency of perineal tears did not differ by pre-delivery BMI (Misan et al., 2022). Nevertheless, studies of individual complications have described an association of excessive GWG with shoulder dystocia (adjusted OR 1.68) (Dude et al., 2021) and of higher body weight with slow labor progress and weaker myometrial contractility (Kapinos et al., 2017; Erbey et al., 2026). Because the composite outcome combined events that may be associated with body weight to different degrees, and individual complications were not analyzed separately, the absence of an association with the composite outcome does not exclude associations with individual complications.

Hypertension and gestational diabetes

The prevalence of hypertension (3.3%) was close to that at the Clinical Hospital Center Rijeka (gestational hypertension 2.73%, preeclampsia 0.70%) (Barišić, 2015), whereas the prevalence of gestational diabetes (1.1%) was lower than in the samples from Rijeka (3.44%) and Split (3.7% in women with normal weight) (Barišić, 2015; Bilić, 2026), than in women with normal weight in a Canadian (4.9%) and a Polish study (6.0%), and than in the entire Chinese sample (26.0%) (Bouvier et al., 2019; Misan et al., 2022; Long et al., 2025). These differences may reflect different diagnostic criteria and screening approaches, but also incomplete recording of diagnoses in the medical records. Both diagnoses were presented only descriptively, so no conclusions can be drawn about their association with BMI and GWG in this sample.

Other factors and model performance

The association of higher parity with lower odds of cesarean delivery is consistent with the literature: primiparous women in a Polish study had six to eleven times higher odds of cesarean delivery (Jaworowski et al., 2025), and in a Turkish cohort cesarean delivery was more frequent in nulliparous than in multiparous women (41.4% vs. 23.1%) (Erbey et al., 2026), which is why some studies analyze nulliparous women separately or exclusively (Kominiarek et al., 2018; Dalbye et al., 2021; Dude et al., 2021). Because parity and gestational age were not linearly associated with the logit of the outcome, their estimates from the linear models should be interpreted with caution. The inverse association with gestational age may reflect planned cesarean deliveries before the spontaneous onset of

labor, which cannot be verified without data on the type of cesarean delivery.

Both models explained a small proportion of the variability in the outcomes (Nagelkerke's R^2 0.112 and 0.070) and had limited discriminative ability (AUC 0.676 and 0.662), similar to a Turkish cohort in which the AUC for BMI alone was 0.678 (Erbey et al., 2026), whereas in a Polish study pre-delivery BMI as the sole predictor had an AUC of 0.550 (Misan et al., 2022). End-of-pregnancy BMI is therefore associated with mode of delivery, but on its own it does not allow reliable prediction of outcomes for individual women, so the estimates should be interpreted as measures of association rather than as a prediction tool.

Clinical implications

End-of-pregnancy BMI is readily available on admission to the delivery ward. These results, along with the findings of Misan et al. (2022) and Erbey et al. (2026), suggest that BMI may be considered one of the factors in assessing the risk of cesarean delivery, together with parity and other clinical factors. However, a statistically significant association does not necessarily imply a clinically significant one, and the limited discriminative ability of the models does not support the use of BMI as a stand-alone prediction tool. The finding that cesarean delivery was associated with end-of-pregnancy BMI rather than with GWG alone is consistent with the emphasis placed in the literature on preconception nutritional status (Bilić, 2026), but without data on pre-pregnancy BMI no conclusions can be drawn about the effects of preconception care. According to an individual participant data meta-analysis cited by Hoek et al. (2022), diet- and physical activity-based interventions during pregnancy reduced GWG by 0.7 kg on average and reduced the odds of cesarean delivery, but not composite adverse maternal and offspring outcomes. Monitoring GWG remains important because of its reported associations with hypertensive disorders, macrosomia, and other adverse outcomes (Kominiarek et al., 2018; Goldstein et al., 2025).

Strengths and limitations

A strength of this study is the analysis of 1070 deliveries over a three-year period, in which end-of-pregnancy BMI and GWG were analyzed as continuous variables and included simultaneously in multivariable models, with assessment of multicollinearity, linearity, and model fit, as well as sensitivity analyses.

The study also has several limitations. The retrospective observational design does not allow conclusions about cause-and-effect relationships, and conducting the study at a single healthcare institution limits the generalizability of the results. Data were obtained from existing medical records, so their completeness and accuracy depend on the quality of documentation, and the analysis did not include all factors that may affect delivery outcomes, such as previous cesarean delivery, labor induction, fetal presentation, indications for and type of cesarean delivery, and neonatal birth weight.

End-of-pregnancy BMI rather than pre-pregnancy BMI was used, which should be taken into account when interpreting the findings. End-of-pregnancy BMI also reflects GWG, so the contributions of baseline nutritional status and GWG cannot be fully separated, and the women could not be classified by nutritional status category or according to the IOM recommendations. The timing of the first visit to the primary care gynecologist, from which body weight at the beginning of pregnancy was obtained, may have differed among women, which may affect the accuracy of the calculated GWG. Different delivery complications (birth canal injuries, shoulder dystocia, and uterine inertia) were combined into a single outcome, although they are clinically distinct events, so the absence of an association with the composite outcome does not exclude associations with individual complications. Uterine inertia may also be an indication for cesarean delivery, so the two outcomes analyzed are not entirely independent. Hypertension and gestational diabetes were analyzed only descriptively.

Parity and gestational age, and in the complications model also GWG, departed from a linear association with the logit of the outcome, although the estimate for BMI did not change materially in the flexible models. Significant Hosmer–Lemeshow tests in both models indicate departures from adequate calibration. Therefore, the association between BMI and cesarean delivery should not be interpreted as evidence that BMI alone allows reliable prediction of outcomes for an individual woman. The models were used to examine associations, not as validated tools for individual risk prediction, and the sensitivity analyses do not constitute external validation or resolve the calibration limitations. These limitations do not necessarily diminish the value of the study, but it is important to present them transparently so that readers can properly understand the results and their scope.

Conclusions

In the study sample of 1070 deliveries, 30.2% of deliveries were cesarean deliveries, and at least one complication was recorded in 36.4%.

Higher end-of-pregnancy BMI was associated with higher odds of cesarean delivery, both in the bivariate analysis and after adjustment for GWG, maternal age, parity, and gestational age.

GWG was not associated with mode of delivery in either the bivariate or the multivariable analysis.

GWG was greater in women with delivery complications, but after adjustment neither GWG nor end-of-pregnancy BMI was significantly associated with complications, whereas higher parity was associated with lower odds of complications.

The models explained a small proportion of the variability in the outcomes and had limited discriminative ability and imperfect calibration; therefore, end-of-pregnancy BMI may be considered one of the factors in assessing the risk of cesarean delivery rather than a stand-alone indicator. Owing to the observational design, the results do not allow causal conclusions. More reliable conclusions require prospective multicenter studies that include pre-pregnancy BMI, individual delivery complications, and the type of cesarean delivery.

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