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Gestational weight gain according to bmi-based recommendations and its association with birth weight: A retrospective cohort study

Firda Fibrila[1]*, M. Ridwan[2], Septi Widiyanti[3]

[1,2,3]Midwifery Study Program Metro Campus, Poltekkes Kemenkes Tanjung Karang, Indonesia

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ABSTRACT

Gestational weight gain (GWG) is a modifiable factor for perinatal outcomes, but its association with birth weight (BW) remains inconsistent. This retrospective cohort study examined GWG, its adequacy against body mass index (BMI)-specific recommendations adjusted for gestational age, and its association with BW and low birth weight (LBW) among 273 women who delivered in three community health centers in Metro City, Indonesia, between January and September 2026. GWG was calculated from pre-pregnancy, second-trimester, and last third-trimester weights (mean 33 weeks). Mean GWG up to the last visit was 8.47 kg (SD 4.08); 41.5%, 38.6%, and 19.9% of women gained inadequately, adequately, and excessively. LBW prevalence was 7.7%. GWG showed no detectable linear correlation with BW ($r = 0.014$; 95% CI −0.105 to 0.133) and was not associated with LBW (adjusted OR 0.99 per kg; 95% CI 0.87–1.13). Adequacy differed by pre-pregnancy BMI category ($p < 0.001$), partly reflecting BMI-specific thresholds, but not by age or gravidity. Lower LBW odds in primigravidae (adjusted OR 0.19; 95% CI 0.04–0.86; two events) is exploratory. Small effects cannot be excluded; gestational age at delivery was unavailable and LBW cases were few.

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Corresponding Author:

Firda Fibrila,
Midwifery Study Program Metro Campus,
Poltekkes Kemenkes Tanjung Karang,
Jl. Brigjen Sutiyoso nomor 1 Kota Metro, Lampung, 34111, Indonesia
Email: firdafibrila@poltekkes-tjk.ac.id

INTRODUCTION

Low birth weight (LBW, <2,500 g) remains a public health issue due to its association with neonatal mortality, growth retardation, and chronic diseases later in life (Bianchi, M. E., & Restrepo, 2022). The global prevalence of LBW was estimated at 14.7% of all newborns in 2020, with higher rates observed in low- and middle-income countries (Okwaraji et al., 2025). In Indonesia, the 2023 Indonesian Health Survey indicated an LBW prevalence of approximately 6.1% (Kemenkes RI, 2023).

Gestational weight gain (GWG) is an indicator that can be monitored during antenatal care. It reflects the combined growth of the fetus, placenta, and amniotic fluid, as well as an increase in

blood volume and changes in maternal tissues. Both insufficient and excessive weight gain have been linked to various adverse pregnancy outcomes. One significant outcome is low birth weight (LBW; <2,500 g), which is associated with an increased risk of neonatal mortality and long-term health issues. Therefore, the assessment of weight gain must consider the mother's nutritional status prior to pregnancy and the stage of pregnancy at which the weight is measured, rather than focusing solely on the absolute change in weight (Kemenkes RI, 2020).

International evidence indicates that the relationship between gestational weight gain (GWG) and infant outcomes is not always linear; it varies depending on whether the weight gain falls below, within, or above recommended ranges. Large-scale meta-analyses have found that GWG below recommendations is associated with an increased risk of infants being small for gestational age (SGA) and preterm birth, while excessive GWG is linked to an increased risk of infants being large for gestational age (LGA), macrosomia, and the need for a cesarean section (Goldstein et al., 2017; Chang, et al., 2021). More recent systematic reviews and meta-analyses have also reported that GWG below recommendations is associated with lower birth weight and a higher risk of low birth weight (LBW) and SGA, whereas GWG above recommendations is linked to higher birth weight and an increased risk of various adverse maternal and neonatal outcomes (Goldstein et al., 2025). These findings underscore the importance of monitoring GWG, while also highlighting that observed outcomes depend on the specific weight-gain category, population characteristics, and the outcomes being analyzed.

Research in Indonesia provides relevant context, yet existing evidence does not fully address how the adequacy of gestational weight gain (GWG)—assessed at different weighing intervals—relates to birth weight and low birth weight (LBW). A cohort study in West Sumatra found that inadequate GWG is associated with lower birth weight, as well as an increased risk of being small for gestational age (SGA) and preterm birth, even after accounting for various maternal characteristics (Aji et al., 2022; Soltani et al., 2017) However, findings from a single region cannot necessarily be generalized to all primary healthcare settings, as population characteristics, antenatal practices, and weight-measurement patterns may vary. Consequently, further local evidence is needed, utilizing routine service data and analytical approaches that account for the timing of measurements and relevant confounding factors.

One methodological challenge in assessing gestational weight gain (GWG) is that weight gain naturally increases as pregnancy progresses. Consequently, weight measured during the second trimester cannot be evaluated in the same way as weight measured near term—which would typically be assessed against total GWG thresholds intended for the end of pregnancy If the gestational age at the time of weighing is ignored, the classification of weight gain—as inadequate, within recommended ranges, or excessive—may be inaccurate. Furthermore, the relationship between GWG and birth weight can be influenced by pre-pregnancy body mass index (BMI), maternal age, parity, and gestational age at delivery. Since birth weight is also affected by the duration of pregnancy, analyses that fail to account for gestational age and maternal characteristics risk producing biased estimates of this relationship. While previous studies have examined GWG and birth outcomes, there remains a practical need to evaluate GWG classifications—based on recommendations adjusted for gestational age at the time of measurement—within the context of primary healthcare in Indonesia, while also investigating their association with birth weight and low birth weight (LBW) after adjusting for maternal characteristics (Richards et al., 2022; Rathjens et al., 2024; Battung et al., 2026).

Based on this gap, this study aims to: (1) describe maternal weight gain (MWG) at various stages of pregnancy; (2) classify the adequacy of MWG based on the recommendations of the Indonesian Ministry of Health—which account for pre-pregnancy body mass index (BMI) and gestational age at the time of weighing—and compare this with a classification method that does not consider gestational age; and (3) analyze the relationship between MWG, birth weight, and the incidence of low birth weight (LBW), while accounting for maternal characteristics available in the

dataset. Utilizing retrospective cohort data from primary healthcare services in Metro City, this study does not claim to develop a new method or establish a causal relationship. Its empirical contribution lies in demonstrating how adjusting for gestational age at the time of measurement can influence the classification of MWG adequacy in routine data, and in providing local estimates regarding the association between these classifications, birth weight, and LBW, after adjusting for measurable confounding factors.

RESEARCH METHOD

This research is an analytical observational study with a retrospective cohort design, utilizing secondary data from the Maternal and Child Health (MCH) Handbook, which was verified against maternal cohort records. The study was conducted at three community health centers (Puskesmas) in Metro City: Yosomulyo, Iringmulyo, and Karangrejo. Data were collected during August and September 2026 through a document review of the records of women who gave birth between January and August 2026.

The sample size was calculated using Cochran's formula with finite population correction (Cochran, 1977; Nanjundeswaraswamy & Divakar, 2021). assuming a 95% confidence level ($Z = 1.96$), a 5% margin of error, and an expected proportion of 50% ($p = q = 0.50$). The required sample was 384.16 for an infinite population, which reduced to 274.58 for a sampling frame of 960 deliveries and was rounded up to 275. This calculation provided precision for estimating a proportion; it was not based on the primary outcomes (birth weight or LBW). With 272 women, the study could detect a correlation of approximately $r = 0.17$ with 80% power ($\alpha = 0.05$, two-sided); however, the number of LBW cases ($n = 21$; 7.7%) limited the multivariable analysis.

A sampling frame consisting of 960 eligible maternal records was established. Each record was assigned a unique identification number ranging from 1 to 960. The identification numbers were entered into the online randomization tool *Wheel of Names* (wheelofnames.com). Simple random sampling was conducted by the research team through repeated spins of the virtual wheel. Each selected identification number was recorded and linked to the corresponding record in the sampling frame. If a previously selected identification number reappeared, it was considered a duplicate and excluded from the sample, and an additional spin was performed to obtain a different identification number. This process was repeated until the predetermined sample size of 275 unique records was achieved. The selected records subsequently underwent data verification and eligibility assessment prior to analysis.

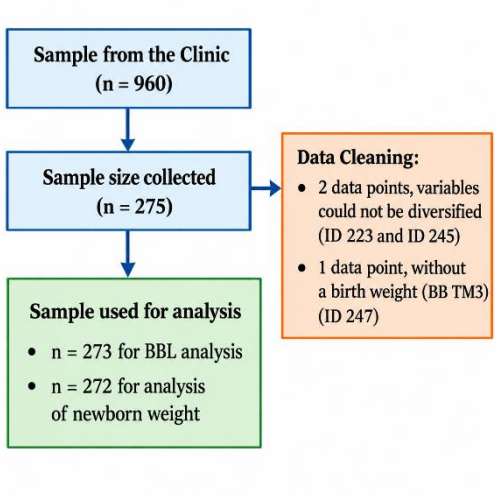


Figure 1. Sample selection flowchart

Following the selection of 275 records, a data verification and cleaning procedure was conducted to ensure data completeness and consistency. During this process, two records were excluded because key variables could not be verified against the original data sources, namely the MCH handbook and maternal cohort registry records. Consequently, 273 records met the eligibility criteria for analysis. One participant lacked a third-trimester weight measurement and was therefore excluded from analyses involving gestational weight gain. However, because birth weight data were available, this participant remained eligible for the birth weight analysis. Accordingly, birth weight analyses included 273 women, whereas gestational weight gain analyses included 272 women. Missing data were handled using a complete-case analysis approach, with sample sizes varying according to data availability for each variable (See Figure 1).

The variables in this study include pre-pregnancy weight (obtained from documented maternal reports), weight during the second trimester, and weight during the third trimester—all of which were measured and recorded in kilograms in the Maternal and Child Health (MCH) handbook. Weight gain was calculated as follows: (a) gain up to the second trimester (second-trimester weight minus pre-pregnancy weight), (b) gain during the third trimester (third-trimester weight minus second-trimester weight), and (c) total gain up to the final visit in the third trimester (third-trimester weight minus pre-pregnancy weight). As no weigh-ins were conducted during the first trimester, weight gain for that period could not be determined separately. Gestational age at the time of weighing was determined based on the first day of the last menstrual period (LMP) and recorded in the MCH handbook; third-trimester weight measurements were taken at a gestational age of 28–39 weeks.

Pre-pregnancy Body Mass Index (BMI) is calculated by dividing body weight by the square of height (m^2) and is categorized as follows: underweight (<18.5), normal (18.5–24.9), overweight (25.0–29.9), and obese (≥30.0 kg/m^2). These categories align with those used in the Ministry of Health's antenatal guidelines (Kemenkes RI, 2020). Maternal age is grouped into <20, 20–35, and >35 years (Akseer et al., 2022; (ACOG et al., 2023). Parity is classified based on the number of pregnancies a woman has experienced: primigravida (G1), multigravida (G2–4), and grand multigravida (G≥5) (Adil & Al-tawil, 2024; (Shperling etal., 2026). Birth weight is obtained from delivery records documented in the MCH handbook. It is measured in grams by healthcare professionals using a digital scale and subsequently categorized as low birth weight (LBW) (<2,500 g), normal birth weight (≥2,500 g), or macrosomia (>4,000 g) (ACOG, 2021; Jones, 2023; Carlo & Renzo, 2026; Hill, 2026). As there were only three infants with macrosomia, this group was not analyzed separately.

Weight gain adequacy was assessed against recommendations established by the Indonesian Ministry of Health, based on BMI. Total weight gain ranges were 12.71–18.16 kg (underweight), 11.35–15.89 kg (normal weight), 6.81–11.35 kg (overweight), and 4.99–9.08 kg (obese), with corresponding third-trimester gain rates of 0.45–0.59, 0.36–0.45, 0.23–0.32, and 0.18–0.27 kg/week (Kemenkes RI, 2020). Since third-trimester weight was measured at a gestational age of 28–39 weeks (rather than at term), the expected gain limit at the time of weighing was calculated as: total limit − rate × (40 − gestational age at weighing), using the lower rate for the lower limit and the upper rate for the upper limit. This approach aligns with gestational age-based methods found in the literature (Hutcheon et al., 2023). Weight gain below the lower limit was classified as inadequate, within the range as adequate, and above the upper limit as excessive.

Data normality was assessed using the Shapiro–Wilk test. Total weight gain and birth weight were not normally distributed (both $p < 0.001$). Comparisons between groups were performed using the Kruskal–Wallis test, while comparisons between paired time points were conducted using the Wilcoxon test. Continuous data are presented as medians. Given the large sample size, Pearson correlation analysis and linear regression with robust standard errors were employed, supplemented by Spearman correlation. Confidence intervals for Pearson correlations

were calculated using the Fisher transformation, which was also used to compare two independent correlation coefficients. Associations between categorical variables were tested using Pearson's chi-square test (when expected counts were sufficient), Fisher's exact test for 2 × 2 tables (when any cell had an expected count < 5), and the Fisher–Freeman–Halton test (using the Monte Carlo method with 20,000 permutations) for larger tables where more than 20% of the cells had expected counts < 5 (Ghasemi, A., & Zahediasl, 2012; Ranganathan, 2021).

Multivariate analysis comprised logistic regression with low birth weight (LBW) as the outcome and linear regression with birth weight as the outcome. Given the limited number of LBW cases (approximately 19–20), the logistic model was restricted to four predictors—weight gain, primigravida status, pre-pregnancy BMI, and age >35 years—to ensure an adequate events-per-variable ratio. Weight gain was included both as a continuous variable (per kg) and as a categorical variable (reference: adequate). The linear model included weight gain, BMI, age, primigravida status, gestational age at weighing, and infant sex, utilizing HC3 robust standard errors ($\alpha = 0.05$). Collinearity was assessed using the variance inflation factor, and homoscedasticity was evaluated via the Breusch-Pagan test. Sensitivity analyses were conducted by excluding (a) mothers with suspected twin pregnancies, (b) birth weights <1,500 g, (c) negative weight gain, (d) birth weights >4,000 g, (e) a combination of these criteria mirroring stricter cohort criteria, and (f) restricting the analysis to a gestational age at weighing of 32–37 weeks. Statistical significance was set at $p < 0.05$ (two-sided). Analyses were performed using SPSS 26. This study received ethical approval from the Research Ethics Committee of Poltekkes Kemenkes Tanjung Karang in February 2026, reference number 103/KEPK-TJK/II/2026.

RESULTS AND DISCUSSIONS

Result

A total of 273 mothers were analyzed. The majority were aged 20–35 years (83.5%) and multigravid (60.8%). Based on pre-pregnancy BMI, 56.8% were of normal weight, 23.1% were overweight, 13.6% were underweight, and 6.6% were obese. The mean birth weight was 3,026.7 g (SD 462.8), with a low birth weight (LBW) prevalence of 7.7% (21 infants). The respondents' characteristics are presented in Table 1.

Table 1. Characteristics of study subjects (n = 273)

Characteristics	n (%) or mean ± SD (range)
Maternal age	
Mean (years)	29.86 ± 5.47 (15–46)
<20 years	5 (1.8)
20–35 years	228 (83.5)
>35 years	40 (14.7)
Parity	
Primigravida	103 (37.7)
Multigravida	166 (60.8)
Grand multigravida	4 (1.5)
Pre-pregnancy anthropometry	
Weight (kg)	56.74 ± 11.95 (34–95)
Height (cm)	155.72 ± 5.48 (135–180)
BMI (kg/m²)	23.34 ± 4.41 (14.72–42.22)
Underweight (<18.5)	37 (13.6)
Normal (18.5–24.9)	155 (56.8)
Overweight (25.0–29.9)	63 (23.1)
Obese (≥30.0)	18 (6.6)
Pregnancy and infant	
Gestational age at third-trimester weighing (weeks)	33.09 ± 2.38 (28–39)
Infant sex: male / female	142 (52.2) / 130 (47.8)
Birth weight (g)	3.026.7 ± 462.8 (1.175–4.800)
Low birth weight (<2,500 g)	21 (7.7)

Characteristics	n (%) or mean ± SD (range)
Weight gain category: insufficient / appropriate / excessive	113 (41.5) / 105 (38.6) / 54 (19.9)

Note: BMI: body mass index; LBW: low birth weight. Sex and weight gain categories were calculated based on 272 mothers with complete data. Weight gain categories were determined using Ministry of Health recommendations, adjusted for gestational age at the time of weighing

Maternal Weight Gain

The mean weight gain until the second trimester was 3.58 kg (SD 3.00), and in the third trimester, it was 4.88 kg (SD 3.26), with a total weight gain reaching 8.47 kg (SD 4.08) (see Table 2). The increase in the third trimester was greater than the increase until the second trimester (Wilcoxon test, $p < 0.001$); however, the length of the two periods was different, so this comparison needs careful interpretation. Based on recommendations adjusted for gestational age, 41.5% of mothers experienced insufficient gain, 38.6% had appropriate gain, and 19.9% had excessive gain. When the total increase is compared directly with the total range without adjustment, the proportions are 63.2% insufficient, 28.7% appropriate, and 8.1% excessive.

Table 2. Pregnant women's weight gain based on trimester period

Period	n	Mean ± SD (kg)	Range (kg)
Pre-pregnancy to second trimester	273	3.58 ± 3.00	−14.0 sampai 14.0
Second trimester to third trimester	272	4.88 ± 3.26	−6.0 sampai 18.0
Total (pre-pregnancy to third trimester)	272	8.47 ± 4.08	−10.0 sampai 22.0

Wilcoxon test for the increase from the second trimester to the third trimester: $p < 0.001$

Weight gain, treated as a continuous variable, differed across maternal age groups (Table 3). Women aged >35 years had the lowest mean third-trimester weight gain (3.95 kg) and total gestational weight gain (7.28 kg), with evidence of differences across age groups ($p = 0.045$ and $p = 0.017$, respectively). Weight gain up to the second trimester also differed by parity ($p = 0.011$), whereas total gestational weight gain showed no evidence of differences by parity ($p = 0.544$) or pre-pregnancy BMI ($p = 0.278$). Estimates for the <20 years age group (n = 5) and the grandemultigravida group (n = 4) should be interpreted with caution because of the very small sample sizes.

Table 3. Maternal weight gain (kg) by maternal characteristics

Characteristics	n	Up to the second trimester	Third trimester	Total
Maternal age				
<20 years	5	4.80 (3.19)	5.20 (3.12)	10.00 (1.41)
20–35 years	228	3.60 (3.00)	5.04 (3.25)	8.64 (3.93)
>35 years	40	3.33 (2.94)	3.95 (3.15)	7.28 (4.81)
p-value		0.412	0.045	0.017
Parity				
Primigravida	103	2.99 (3.24)	5.59 (3.66)	8.58 (4.70)
Multigravida	166	3.86 (2.73)	4.48 (2.88)	8.34 (3.59)
Grand multipara	4	7.25 (2.86)	3.23 (3.09)	10.47 (4.71)
p-value		0.011	0.077	0.544
Pre-pregnancy BMI				
Underweight	37	4.03 (2.64)	5.36 (3.82)	9.39 (4.09)
Normal	155	3.48 (2.66)	4.91 (3.37)	8.39 (3.87)
Overweight	63	3.83 (3.37)	4.76 (2.83)	8.59 (4.22)
Obese	18	2.66 (4.44)	4.10 (1.93)	6.76 (4.60)
p-value		0.239	0.745	0.278

Maternal Characteristics and Adequacy of Weight Gain

The adequacy of weight gain was significantly related to pre-pregnancy BMI ($p < 0.001$), but not to maternal age ($p = 0.119$) or parity ($p = 0.622$) (see Table 4). Under-gain was found in 54.1% of mothers with a lower BMI and 51.9% of mothers with a normal BMI, while excessive gain was found in 46.0% of mothers with a higher BMI. In an alternative analysis without adjustment

for gestational age, the association with BMI remained significant ($p < 0.001$) and the association with age remained non-significant ($p = 0.169$), while the association with parity became significant ($p = 0.038$), indicating that the parity results were unstable relative to categorical definitions.

Table 4. Distribution of gestational weight gain adequacy categories by maternal characteristics

Characteristics	not enough n (%)	Appropriate n (%)	excessive n (%)	Total	p-value
Maternal age					
<20 years	1 (20.0)	4 (80.0)	0 (0.0)	5	
20–35 years	90 (39.6)	89 (39.2)	48 (21.1)	227	0.119[a]
>35 years	22 (55.0)	12 (30.0)	6 (15.0)	40	
Parity					
Primigravida	45 (43.7)	40 (38.8)	18 (17.5)	103	
Multigravida	67 (40.6)	64 (38.8)	34 (20.6)	165	0.622[a]
Grand multipara	1 (25.0)	1 (25.0)	2 (50.0)	4	
Pre-pregnancy BMI					
Underweight	20 (54.1)	11 (29.7)	6 (16.2)	37	
Normal	80 (51.9)	62 (40.3)	12 (7.8)	154	<0.001[b]
Overweight	11 (17.5)	23 (36.5)	29 (46.0)	63	
Obese	2 (11.1)	9 (50.0)	7 (38.9)	18	

Association with Birth Weight

Weight gain categories were not associated with low birth weight (LBW) (inadequate: 6.2%, adequate: 7.6%, excessive: 9.3%; $p = 0.770$) (see Table 5). Mean birth weights were also similar across categories: 3,015 g (SD 364) for inadequate gain, 3,054 g (SD 474) for adequate gain, and 3,032 g (SD 558) for excessive gain (Kruskal-Wallis, $p = 0.731$). Similar results were obtained without adjustment for gestational age (LBW rates of 7.0%, 7.7%, and 9.1%; $p = 0.929$). Maternal age ($p = 0.356$), pre-pregnancy BMI ($p = 0.419$), and infant sex ($p = 0.503$) were also not associated with LBW. The only variable associated with LBW was parity ($p = 0.036$): LBW was observed in 1.9% of primigravidae (2 out of 103) and 11.4% of multigravidae (19 out of 166), with no cases among the four grandemultigravidae. When primigravidae were compared with all other mothers, the difference remained significant (Fisher's exact test, $p = 0.004$).

Table 5. Cross-tabulation of maternal characteristics and weight gain against the incidence of low birth weight (LBW)

Variabel	LBW n (%)	Not LBW n (%)	Total	p-value
Maternal age				
<20 years	0 (0.0)	5 (100.0)	5	
20–35 years	16 (7.0)	212 (93.0)	228	0.356[a]
>35 years	5 (12.5)	35 (87.5)	40	
Parity				
Primigravida	2 (1.9)	101 (98.1)	103	
Multigravida	19 (11.4)	147 (88.6)	166	0.036[a]
Grand multipara	0 (0.0)	4 (100.0)	4	
Pre-pregnancy BMI				
Underweight	2 (5.4)	35 (94.6)	37	
Normal	12 (7.7)	143 (92.3)	155	0.419[a]
Overweight	7 (11.1)	56 (88.9)	63	
Obese	0 (0.0)	18 (100.0)	18	
Weight gain categories				
Insufficient	7 (6.2)	106 (93.8)	113	
Appropriate	8 (7.6)	97 (92.4)	105	0.770[b]
Excessive	5 (9.3)	49 (90.7)	54	
Baby's gender				
Male	9 (6.3)	133 (93.7)	142	0.503[b]
Female	11 (8.5)	119 (91.5)	130	

Note: The number of mothers in the category of weight gain and baby gender was 272

The correlation between weight gain and birth weight was very weak and not statistically significant (Table 6). Total gain (r = 0.014; CI 95%: -0.105 to 0.133; p = 0.816), gain up to the second trimester (r = 0.061), and third-trimester gain (r = -0.041) all demonstrated this weak correlation. After excluding low birth weight (LBW) infants (n = 252), the total correlation remained near zero (r = 0.037; p = 0.554). Uterine fundal height showed the strongest positive Pearson correlation among the variables studied (r = 0.110; p = 0.070), although the relationship remained weak and did not reach statistical significance. In the Spearman analysis, only pre-pregnancy weight showed a significant—albeit very weak—correlation with birth weight (ρ = 0.138; p = 0.022), whereas the Pearson correlation was not significant (r = 0.086; p = 0.156).

Table 6. Correlation of maternal variables with birth weight

Variable	n	Pearson r (p)	Spearman ρ (p)
Total weight gain	272	0.014 (0.816)	0.049 (0.423)
Increase until the second trimester	273	0.061 (0.319)	0.095 (0.116)
Third trimester increase	272	−0.041 (0.498)	−0.021 (0.737)
Maternal age	273	0.026 (0.667)	0.101 (0.096)
Pre-pregnancy weight	273	0.086 (0.156)	0.138 (0.022)
Pre-pregnancy BMI	273	0.077 (0.204)	0.108 (0.075)
Gestational age at weighing	272	0.070 (0.250)	0.046 (0.448)
Height of the uterine fundus	271	0.110 (0.070)	0.116 (0.056)

Note: Dependent variable: birth weight (g)

In the logistic regression analysis (n = 271; 19 cases of low birth weight/LBW), weight gain was not associated with LBW, whether treated as a continuous variable (OR 0.99 per kg; 95% CI 0.87–1.13; p = 0.890) or a categorical variable (inadequate vs. adequate: OR 0.76; excessive vs. adequate: OR 1.03); see Table 7. Primigravidae continued to show lower odds of LBW (adjusted OR 0.19; 95% CI 0.04–0.86; p = 0.031), although the confidence interval was very wide. Results were similar without adjustment for gestational age (inadequate: OR 0.97; excessive: OR 1.49; neither statistically significant). The model's discrimination ability was low (AUC 0.67). the estimate is imprecise and should be considered exploratory.

Table 7. Logistic regression of factors associated with low birth weight (LBW)

Variable	Model 1 OR (CI 95%)	p	Model 2 OR (CI 95%)	p
Total weight gain (per kg)	0.99 (0,87–1,13)	0.890	–	–
Inadequate gain (vs. appropriate)	–	–	0.76 (0.26–2.22)	0.609
Excessive gain (vs. appropriate)	–	–	1.03 (0.28–3.81)	0.960
Primigravida (vs. others)	0.19 (0.04–0.85)	0.030	0.19 (0.04–0.86)	0.031
Pre-pregnancy BMI (per kg/m²)	0.98 (0.87–1.10)	0.691	0.97 (0.86–1.09)	0.624
Age >35 years	1.57 (0.51–4.85)	0.435	1.68 (0.54–5.17)	0.369

Note: Model 1: continuous weight gain; Model 2: weight gain categories (adjusted for gestational age). n = 271; 19 cases of low birth weight. OR: odds ratio

In the linear regression analysis (Table 8), weight gain was not associated with birth weight (B = 4.1 g per kg; 95% CI -11.1 to 19.3; p = 0.596; bootstrap results were similar). No significant predictors were identified; female infants tended to weigh 98 g less (p = 0.072), and infants of primigravid women tended to weigh 102 g more (p = 0.106). The overall model explained only 3.5% of the variation in birth weight (R^2 = 0.035). There was no evidence of multicollinearity (VIF ≤ 1.32) or heteroskedasticity (p = 0.461). After excluding low birth weight (LBW) infants, weight gain remained nonsignificant (p = 0.332), whereas pre-pregnancy BMI became marginally significant (11.2 g per kg/m²; p = 0.044).

Table 8. Linear regression of factors associated with birth weight (g)

Variable	Model A B (CI 95%)	p	Model B B (CI 95%)	p
Total weight gain (per kg)	4.1 (−11.1 – 19.3)	0,596	–	–

Variable	Model A B (CI 95%)	p	Model B B (CI 95%)	p
Inadequate gain (vs. appropriate)	–	–	−41.5 (−157.4 – 74.4)	0.483
Excessive gain (vs. appropriate)	–	–	−11.7 (−187.8 – 164.4)	0.897
Pre-pregnancy BMI (per kg/m²)	9.9 (−2.1 – 21.8)	0.105	8.3 (−5.3 – 22.0)	0.231
Maternal age (per year)	4.9 (−5.5 – 15.3)	0.358	5.1 (−5.4 – 15.6)	0.345
Primigravida (vs. others)	101.8 (−21.7 – 225.3)	0.106	102.6 (−21.8 – 227.0)	0.106
Gestational age at weighing (per week)	10.6 (−12.5 – 33.7)	0.370	12.0 (−11.0 – 35,0)	0.305
Female infant (vs. male)	−98.1 (−204.9 – 8.6)	0.072	−97.6 (−205.0 – 9.8)	0.075

Note: HC3 robust standard error; n = 271. Model A: $R^2 = 0.035$; Model B: $R^2 = 0.035$

Excluding subjects based on stricter criteria did not alter the conclusions (Table 9). The correlation between total weight gain and birth weight remained between −0.024 and 0.060, and the odds ratio for primigravidae remained 0.16–0.18. The only change occurred when the analysis was restricted to mothers weighed at 32–37 weeks of gestation (n = 197); as there were no cases of low birth weight among primigravidae, the logistic model could not be estimated due to perfect separation.

Table 9. Sensitivity analysis regarding exclusion criteria

Scenario	n	Pearson r (p)	OR primigravida (p)
All data	272	0.014 (0.816)	0.17 (0.018)
Excluding suspected twin pregnancy	271	0.019 (0.760)	0.17 (0.021)
Excluding birth weight <1,500 g	271	0.045 (0.460)	0.17 (0.022)
Excluding negative weight gain	268	0.052 (0.393)	0.17 (0.019)
Excluding birth weight >4,000 g	269	−0.024 (0.696)	0.16 (0.018)
Combined criteria above	263	0.056 (0.368)	0.18 (0.027)
Gestational age at weighing 32–37 weeks only	197	0.093 (0.196)	cannot be estimated*

Discussion

The main finding of this study is that maternal weight gain measured up to the third trimester was not statistically associated with birth weight or low birth weight in either bivariate or adjusted analyses. However, the absence of statistical significance should not be interpreted as proof of no association. Rather, the estimated effects were small and accompanied by uncertainty, as reflected in the confidence intervals. This correlation is weaker than that reported in a previous study in Medan (r = 0.213) (Lumbanraja S, Lutan D, 2013), although the difference between the two studies was not statistically significant (p = 0.083). Insufficient statistical power does not explain this finding: with 272 subjects, the study was capable of detecting a correlation of approximately 0.17 with 80% power (approximately 94% for r = 0.213); the upper limit of the 95% confidence interval (0.133) did not include 0.213, and the bootstrap interval yielded similar results (−0.114 to 0.144). The difference between studies may reflect differences in sampling variability, measurement timing, population characteristics, and analytical approaches. Because the Medan study included a smaller sample, its effect estimate was less precise; however, the available evidence does not allow definitive conclusions regarding the source of the discrepancy. Comparisons with previous studies should be interpreted in the context of methodological differences. In contrast to the Medan study, the present analysis assessed weight gain at the last third-trimester antenatal visit rather than near delivery. In addition, differences in population characteristics, clinical setting, gestational-age distribution, and statistical adjustment strategies may contribute to differences in observed associations.

Several methodological points warrant consideration. First, because gestational age at delivery was unavailable, the observed lack of association between maternal weight gain and birth weight should be interpreted cautiously. Gestational age at delivery is a major determinant of birth weight and may confound or modify the relationship under investigation. Second, the absence of gestational age at delivery made it impossible to distinguish between preterm infants and those small for gestational age, potentially masking the signal of weight gain amidst gestational age variations. Third, the limited number of LBW cases reduced precision and increased uncertainty

around the estimated odds ratios, making it difficult to exclude potentially meaningful associations. Fourth, maternal weight gain includes components unrelated to the fetus—such as extracellular fluid, adipose tissue, and edema—resulting in a generally weak correlation with birth weight at the individual level (Kominiarek, 2017). Collectively, the models explained only 3.5% of the variation in birth weight, underscoring that the primary determinants of birth weight lie beyond the available variables.

The empirical findings regarding maternal weight gain should be distinguished from classifications based on guideline-defined recommendations. Empirically, mothers with lower pre-pregnancy BMI tended to achieve lower pregnancy weight gain, whereas excessive weight gain was more frequently observed among mothers with higher pre-pregnancy BMI. Similar patterns have been reported in previous studies, which found that women entering pregnancy with overweight or obesity are more likely to exceed recommended gestational weight-gain ranges, whereas women with lower BMI are more likely to gain below recommended targets (Kominiarek & Peaceman, 2017; Goldstein et al., 2017) When these observed weight gains were evaluated against recommended gestational weight-gain ranges, 54.1% of women classified as underweight and 51.9% of women classified as normal weight did not reach the recommended range, whereas 46.0% of women in the higher-BMI category exceeded the recommended range. These percentages reflect concordance with guideline-defined targets rather than direct evidence of adverse maternal or neonatal outcomes. These weight gain categories based on BMI are established by the Ministry of Health of the Republic of Indonesia and are intended as a guide for optimal weight gain during pregnancy at the population level, rather than as a direct indicator of adverse outcomes in individual pregnancies (Kemenkes RI, 2020; (Burnie & Golob, 2022; Chahal et al., 2025). These empirical observations describe patterns observed in the study population, whereas classifications of inadequate, adequate, and excessive weight gain originate from external guideline recommendations and should not be interpreted as outcomes in themselves.

The estimated prevalence of inadequate weight gain varied substantially according to the method used to apply the recommendations. When gestational age at weighing was taken into account, 41.5% of mothers were classified as having inadequate weight gain. In contrast, when weight gain achieved before term was compared directly with recommendations intended for delivery at term, the proportion increased to 63.2%. This discrepancy demonstrates that assessments of gestational weight-gain adequacy are highly sensitive to gestational age at measurement. Because total gestational weight gain is intrinsically related to pregnancy duration, comparisons that ignore gestational age at weighing may misclassify women and overestimate the prevalence of inadequate weight gain (Bodnara et al., 2015; Hutcheon et al., 2023). Therefore, studies evaluating gestational weight-gain adequacy should explicitly account for gestational age at measurement and clearly report the timing of weight assessment when interpreting adherence to guideline recommendations.

The proportion of mothers assessed as having inadequate weight gain depends heavily on the method used to apply the recommendations. It is 41.5% when adjusted for gestational age at the time of weighing, but 63.2% when weight gain achieved by approximately 33 weeks is compared directly against the total range up to term. Such a direct comparison tends to overestimate inadequacy; therefore, reports on weight gain adequacy should specify the gestational age at the time of weighing. Interestingly, the adequacy of weight gain did not differ significantly by maternal age ($p = 0.119$) or parity ($p = 0.622$) in the primary analysis, although weight gain—treated as a continuous variable—was lower among mothers aged >35 years (7.28 kg vs. 8.64 kg). An association between parity and weight gain adequacy emerged only in the unadjusted analysis, meaning it cannot be considered a robust finding.

The observed association between primigravidity and lower odds of LBW should be considered exploratory rather than confirmatory: LBW was far less common among primigravidae (1.9%) than among multigravidae (11.4%). This finding should not be interpreted as evidence that

primigravidity protects against LBW. Instead, it identifies a pattern in the current dataset that warrants further investigation. Given the small number of events and the absence of several important covariates, the estimate remains uncertain despite statistical significance. The adjusted odds ratio for primigravidity was 0.19 (95% CI 0.04-0.86), although the wide confidence interval indicates substantial uncertainty regarding the magnitude of the association.

However, systematic reviews generally report that nulliparity is associated with an increased risk of LBW and preterm birth compared to low parity (Kashani-ligumsky et al., 2024; Rashash et al., 2025), meaning the direction of this finding is contrary to established evidence. Possible explanations include population characteristics and facility referral patterns, differences in gestational age at birth, and the fact that only two cases of LBW occurred among primigravidae—resulting in an imprecise estimate (95% CI 0.04–0.86) that disappeared when the analysis was restricted to a narrower subsample. As the baseline data did not control for gestational age at birth, history of prior LBW, or pregnancy complications, this finding should be regarded as a hypothesis requiring confirmation. It should also be noted that most variables tested against LBW were not significant, and the tests were conducted without correction for multiple comparisons; thus, a single significant result could have arisen by chance. Ultimately, an important contribution of this study is the demonstration that estimates of inadequate gestational weight gain vary markedly according to whether gestational age at measurement is considered. This finding highlights a methodological issue that may affect interpretation and comparability across studies.

Several limitations should be considered when interpreting the findings. First, gestational age at delivery was unavailable, preventing differentiation between preterm birth and fetal growth restriction and potentially obscuring associations between maternal weight gain and birth weight. Second, maternal weight gain was measured at varying gestational ages during the third trimester rather than at delivery, which may have underestimated total gestational weight gain and attenuated observed associations. Third, important confounders, including pregnancy complications, smoking status, dietary intake, and socioeconomic circumstances, were unavailable; therefore, residual confounding cannot be excluded. Fourth, the relatively small number of LBW cases resulted in wide confidence intervals and reduced precision of the logistic regression estimates, particularly for subgroup analyses and the observed association with primigravidity. Consequently, findings related to LBW should be interpreted as exploratory and require confirmation in larger studies with complete pregnancy and delivery information.

CONCLUSION

In this study, maternal weight gain measured up to the final third-trimester antenatal visit was not significantly associated with birth weight or low birth weight (LBW). The observed effect sizes were small, suggesting that weight gain recorded before delivery explained only a limited proportion of the variation in birth weight within this population. However, interpretation of these findings should consider that gestational age at delivery was unavailable and maternal weight gain was not measured through term, which may have reduced the ability to detect modest associations. The adequacy of gestational weight gain was significantly associated with pre-pregnancy BMI, indicating that women entering pregnancy with different BMI categories experienced different patterns of adherence to guideline-recommended weight-gain ranges. In contrast, maternal age was not significantly associated with weight-gain adequacy in the primary analysis. An exploratory association was observed between parity and LBW, but this finding should be interpreted cautiously because of the small number of LBW cases and the absence of information on gestational age at delivery and other important birth-related factors. This study contributes evidence from routine antenatal-care data that assessments of gestational weight-gain adequacy are highly dependent on both pre-pregnancy BMI and gestational age at the time of measurement. From a practical perspective, monitoring of maternal weight gain during antenatal care should therefore consider BMI-specific recommendations and gestational age at weighing.

Future studies should employ prospective designs and incorporate more comprehensive birth data, including gestational age at delivery and other key determinants of birth outcomes, to provide more precise estimates of the relationship between maternal weight gain and neonatal outcomes.

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