(International Print/Online Journal)

SJIF IMPACT FACTOR: 6.829
PUBMED-National Library of Medicine ID-101739732

ISSN (Print): 2209-2870
ISSN (Online): 2209-2862

International Journal of Medical Science and Current Research (IJMSCR)
Available online at: www.ijmscr.com
Volume 9, Issue 4, Page No: 284-295
July-August 2026

IJMSCR

Association of First-Trimester Body Mass Index and Gestational Weight Gain with Neonatal Birth Weight: A Prospective Observational Study

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Type of Publication: Original Research Paper
Conflicts of Interest: Nil

Abstract

Background: Maternal anthropometry, particularly first-trimester body mass index (BMI) and gestational weight gain (GWG), has been recognized as an important determinant of fetal growth. This study aimed to analyse the influence of early pregnancy BMI on neonatal birth weight and the association between GWG and neonatal outcomes.

Methods: This prospective observational study was conducted at the Department of Obstetrics & Gynaecology, Dr KNS Memorial Institute of Medical Sciences, Barabanki, over 18 months. A total of 130 pregnant women with singleton pregnancies, enrolled by 10 weeks of gestation, were followed up until delivery. First-trimester BMI was categorized per WHO criteria, and GWG was classified as inadequate, adequate, or excessive per IOM 2009 guidelines. The primary outcome was neonatal birth weight. Data were analysed using IBM SPSS 25.0; chi-square test was used, with $p<0.05$ considered significant.

Results: Mean age was 27.86±6.32 years. BMI distribution was: underweight 12.3%, normal 52.3%, overweight 27.7%, and obese 7.7%. Inadequate GWG was observed in 61.5%, adequate in 34.6%, and excessive in 3.8%. Low birth weight (<2.5 kg) occurred in 46.2%. First-trimester BMI showed significant association with birth weight for gestational age ($p<0.001$) and low birth weight ($p<0.001$). GWG demonstrated significant association with birth weight for gestational age ($p<0.001$) and low birth weight ($p<0.001$). Apgar <7 at 1 minute was significantly associated with GWG ($p=0.021$).

Conclusion: First-trimester BMI and gestational weight gain are significantly associated with neonatal birth weight. Inadequate GWG and lower BMI are important risk factors for low birth weight.

Keywords: Body mass index, gestational weight gain, low birth weight, large-for-gestational-age (LGA), small-for-gestational-age (SGA)

Introduction

Low birth weight (LBW) is defined by the World Health Organization as birth weighs less than 2500 grams irrespective of gestational age. It affects approximately 15-20% of newborns globally. Over 20 million babies born with LBW each year [1]. India contributes substantially to this burden, with about 18% of newborns having birth weight below 2.5 kg according to National Family Health Survey-5 data [2]. Maternal anthropometry has long been recognized as a predictor of pregnancy outcomes. Among various parameters, pre-pregnancy body mass index (BMI) and gestational weight gain (GWG) are considered cost-effective, require minimal technical skills, and are suitable for low-resource settings [3]. The Institute

of Medicine (IOM) provides GWG guidelines based on pre-pregnancy BMI categories: underweight (12.5-18 kg), normal weight (11.5-16 kg), overweight (7-11.5 kg), and obese (5-9 kg) [4].

Insufficient GWG is associated with increased risk of small-for-gestational-age (SGA) infants and low birth weight (LBW), while excessive GWG increases risk of large-for-gestational-age (LGA) infants, macrosomia, and caesarean delivery [5-7]. Evidence suggests that maternal underweight increases the risk of LBW and SGA births, whereas overweight and obesity are linked with fetal overgrowth [8,9]. Given the limited recent studies evaluating the relationship of first-trimester BMI and GWG with birth weight from Northern India, this study was conducted to analyse the influence of early pregnancy BMI on neonatal birth weight and to study the association between GWG and neonatal birth weight.

Material And Methods

This prospective observational study was conducted in the Department of Obstetrics & Gynaecology, Dr KNS Memorial Institute of Medical Sciences, Barabanki, over 18 months. The study protocol, data collection tools, consent forms, and patient information sheets were reviewed and approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants after explaining the procedure, risks, and requirements in the local language. Patient confidentiality was maintained using unique Patient IDs. This study adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for cohort studies.

Expectant mothers with singleton pregnancies who attended regular prenatal care by the 10th week of gestation, had at least three antenatal visits, and could be followed up till delivery were included in the study. Female patients with age <18 or >45 years, hyperemesis gravidarum, hypertension, endocrine disorders, multiple pregnancies, preterm delivery (<37 weeks), medical or systemic complications during pregnancy, <3 antenatal visits, lost to follow-up, or abortion were excluded from the study. Sample size was calculated using the formula $n = [z^2 \times p \times (1-p)] / d^2$, where z=1.96 (95% confidence interval), p=0.50 (estimated proportion), d=0.10 (absolute precision), with 10% attrition. Calculated sample size was 107; 130 women fulfilling criteria were enrolled.

Participant data were collected using a pre-established proforma. Demographic information and BMI were documented at the booking visit (by 10th week). Maternal weights were recorded in first (11-12 weeks), second (27-28 weeks), and third trimesters (36-37 weeks). Gestational age at delivery and neonatal birth weight were extracted from delivery case sheets.

Operational definitions

1. Maternal BMI (WHO criteria): Underweight (<18.5 kg/m²), normal (18.5-24.9 kg/m²), overweight (25.0-29.9 kg/m²), obese (≥30 kg/m²).
2. Birth weight by gestational age: SGA (<2.5 kg), AGA (2.5-3.5 kg), LGA (>3.5 kg).
3. GWG per IOM 2009 guidelines: Based on actual weight gain relative to recommended ranges for each BMI category (inadequate, adequate, excessive).

Data were analysed using IBM SPSS 25.0. Qualitative data were presented as numbers and percentages, continuous data as mean ± standard deviation. Association of BMI and GWG with outcomes was evaluated using chi-square test; $p<0.05$ was considered statistically significant.

Results

A total of 130 pregnant women were enrolled in this prospective observational study. The maternal age of the participants ranged from 18 to 39 years, with an overall mean age of 27.86 ± 6.32 years. The relatively higher maternal age observed in the present study may reflect the demographic characteristics of the study population, which predominantly comprised women from urban and peri-urban areas. A stratification of the cohort by age revealed that a young obstetric population predominated, with nearly two-thirds of the participants (62.3%, n = 81) being ≤ 30 years of age. The mean maternal age of approximately 27 years likely reflects the urban and peri-urban population of the Lucknow region, where delayed marriage, higher educational status, employment, and planned pregnancies are increasingly common, resulting in a relatively older obstetric population.

In terms of obstetric history, more than half of the enrolled women were primiparous (53.1%, n = 69), indicating a high proportion of first-time mothers in the study. Geographical distribution was roughly equivalent, with a slight majority of the participants

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residing in urban areas (50.8%, n = 66). Regarding socioeconomic stratification, the majority of the study cohort belonged to the lower-to-middle socioeconomic class (66.9%, n = 87). The baseline haematological assessment at the time of enrolment showed a mean maternal haemoglobin level of 11.27±1.04\text g/dL. Notably, maternal anaemia (defined as a haemoglobin level < 11 g/dL according to standard guidelines) was highly prevalent, affecting more than one-third of the study population (37.7%, n = 49).

Among the 130 pregnant women included in the study, mean weight at enrolment was 58.66±10.31 kg, increasing to 62.72±10.22 kg in second trimester and 67.72±10.46 kg in third trimester. The majority belonged to the normal BMI category as shown in table 1 and figure 1. A total of 68 participants (52.3%) had a first-trimester BMI within the normal range (18.5–24.9 kg/m²). Overweight women (BMI 25.0–29.9 kg/m²) constituted the second largest group, accounting for 36 participants (27.7%). Underweight women (BMI <18.5 kg/m²) comprised 16 participants (12.3%), while obesity (BMI ≥30 kg/m²) was observed in 10 participants (7.7%). Approximately one-third of the study population was either overweight or obese at the beginning of pregnancy. The tracking of maternal weight from the first trimester through to the time of delivery revealed a collective mean Gestational Weight Gain (GWG) of 9.06 ± 1.65 kg across the entire study cohort (N = 130).

When the study population was stratified into distinct clinical categories based on standard weight gain recommendations (table 2 & figure 2), a pronounced skew toward suboptimal weight accumulation was observed. The overwhelming majority of the participants fell into the Inadequate GWG category, representing 61.5% (n = 80) of the total cohort.

Conversely, Adequate GWG — signifying ideal adherence to gestational weight targets—was attained by roughly one-third of the enrolled women (34.6%, n = 45). Maternal weight gain exceeding the recommended physiological thresholds was rare; only a minor fraction of the study population (3.8%, n = 5) was classified as having Excessive GWG.

First-trimester BMI (table 3 and figure 3) showed a statistically significant association with birth weight for gestational age ($\chi^2 = 51.035$; $p < 0.001$). Among underweight mothers, 8 out of 16 neonates (50.0%) were small for gestational age (SGA), 7 (43.8%) were appropriate for gestational age (AGA), and 1 (6.3%) was large for gestational age (LGA). In the normal BMI category, 42 of 68 neonates (61.8%) were SGA, 25 (36.8%) were AGA, and only 1 (1.5%) was LGA.

In contrast, overweight and obese mothers showed a higher proportion of AGA and LGA neonates. Among overweight women, only 2 out of 36 neonates (5.6%) were SGA, whereas 31 (86.1%) were AGA and 3 (8.3%) were LGA. Similarly, among obese women, 1 out of 10 neonates (10.0%) was SGA, 5 (50.0%) were AGA, and 4 (40.0%) were LGA.

These findings suggest that lower maternal BMI was associated with a greater frequency of SGA neonates, while higher BMI categories, particularly obesity, were associated with an increased occurrence of AGA and LGA neonates.

Gestational weight gain (GWG) showed a statistically significant association (table 4 and figure 4) with birth weight for gestational age ($\chi^2 = 76.076$; $p < 0.001$). Among women with inadequate GWG, 49 out of 80 neonates (61.3%) were small for gestational age (SGA), 30 (37.5%) were appropriate for gestational age (AGA), and only 1 (1.3%) was large for gestational age (LGA). In contrast, women with adequate GWG had predominantly AGA neonates. Among the 45 women in this category, 37 neonates (82.2%) were AGA, while 4 (8.9%) were SGA and 4 (8.9%) were LGA.

Excessive GWG was strongly associated with LGA neonates. Among the 5 women with excessive GWG, 4 neonates (80.0%) were LGA and 1 (20.0%) was AGA, while no SGA neonates were observed in this group. These findings indicate that inadequate gestational weight gain was associated with a higher frequency of SGA neonates, whereas excessive GWG was associated with an increased occurrence of LGA neonates. Adequate GWG was predominantly associated with AGA birth weight outcomes.

Other findings

Proportion of SGA neonates was highest among underweight (50.0%) and normal BMI (61.8%) women, while LGA neonates were more common among obese (40.0%) and overweight (8.3%) women. Low birth weight occurred in 56.3% of underweight and 70.6% of normal BMI women compared to only 5.6% of overweight and 10.0% of obese women.

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Inadequate gestational weight gain (GWG) was strongly associated with adverse neonatal outcomes. Among women with inadequate GWG, 61.3% delivered small-for-gestational-age (SGA) neonates, while 70.0% gave birth to low-birth-weight (LBW) infants. Conversely, excessive GWG was predominantly associated with large-for-gestational-age (LGA) neonates, with 80.0% of women in this group delivering LGA babies. Furthermore, the distribution of the 1-minute Apgar score differed significantly across GWG categories ($p = 0.021$). An Apgar score <7 at 1 minute was observed in 60.5% of women with adequate GWG and 60.0% of those with excessive GWG, indicating a significant association between gestational weight gain and early neonatal adaptation.

No significant association was found between first-trimester BMI and maternal complications (hypertensive disorders, GDM, intrahepatic cholestasis), antepartum/intrapartum complications (oligohydramnios, PPROM, APH, fetal distress, preterm delivery, operative delivery), or postpartum complications. Similarly, GWG did not show significant association with these outcomes except for Apgar score at 1 minute.

Discussion

Low birth weight remains a major public health concern, particularly in developing countries like India where maternal undernutrition, poor antenatal care, and socioeconomic inequalities contribute significantly to its burden [1,2]. The present study evaluated the association of first-trimester BMI and GWG with neonatal birth weight in 130 pregnant women.

The mean age of participants (27.86±6.32 years) is comparable to studies by Patel et al. [10] and Mohapatra et al. [11]. The predominance of women from lower-to-middle socioeconomic classes (66.9%) reflects the population profile typically attending government facilities, similar to observations by Lakshmi and Rajkumar [12] and Mishra et al. [13].

The prevalence of underweight (12.3%), normal weight (52.3%), overweight (27.7%), and obesity (7.7%) in our study is consistent with Rajendra et al. [14] and Mythili et al. [15]. However, wide variations exist across Indian studies, with Lakshmi and Rajkumar [12] reporting 48.6% underweight and no obese patients, while Gul et al. [16] found 49% overweight/obese, reflecting regional differences in nutritional status.

Inadequate GWG was observed in 61.5% of women, similar to findings by Paneru and Thapa [17] and Trivikrama et al. [18]. The high prevalence of inadequate GWG observed in the present study may be attributed to the predominantly lower socioeconomic background of the study population, where limited access to adequate nutrition, food insecurity, lower educational status, and suboptimal maternal health awareness may adversely affect maternal weight gain during pregnancy. Additionally, the study's strict exclusion criteria, which excluded women with pre-existing medical disorders and pregnancy-related complications, resulted in a relatively homogeneous low-risk cohort, potentially influencing the overall distribution of gestational weight gain.

The significant association between first-trimester BMI and birth weight ($p<0.001$) aligns with multiple studies. Liu et al. [8] in their meta-analysis concluded that maternal underweight increases risk of LBW and SGA births. Gul et al. [16] and Chowdhury and Choudhury [19] also demonstrated significant association between BMI and birth weight. However, some researchers like Bhowmik et al. [20] and Paneru and Thapa [17] did not find this association significant, possibly due to smaller sample sizes or population differences.

The significant association between GWG and birth weight ($p<0.001$) in our study is consistent with Patil and Yatam [21] and Trivikrama et al. [18]. The finding that 70.0% of women with inadequate GWG delivered LBW babies emphasizes the critical importance of adequate weight gain during pregnancy. This is supported by the systematic review by Goldstein et al. [7] involving 1.6 million women, which demonstrated that insufficient GWG is associated with higher risk of SGA infants and LBW.

The lack of significant association between BMI and GWG with most maternal complications in our study may be attributable to the smaller sample size and strict exclusion criteria that eliminated women with pre-existing or developing medical complications. Studies with larger sample sizes, such as Rajendra et al. [14] (n=540) and Trivikrama et al. [18] (n=296),

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did demonstrate significant associations with hypertensive disorders and GDM.

Conclusion

First-trimester maternal BMI and gestational weight gain were significantly associated with neonatal birth weight. Women with lower BMI and inadequate gestational weight gain were at a higher risk of delivering low-birth-weight infants, highlighting the importance of optimal maternal nutritional status during pregnancy. The high prevalence of inadequate gestational weight gain observed in the study emphasizes the need for routine assessment of maternal BMI in early pregnancy and regular monitoring of weight gain throughout gestation. Incorporating timely nutritional counselling and individualized antenatal interventions may help optimize gestational weight gain and improve neonatal outcomes. These findings support the integration of maternal nutritional assessment and weight monitoring into standard antenatal care to reduce the burden of low birth weight, particularly in resource-limited settings.

This was a single-centre study with a relatively modest sample size, which may limit the generalizability of the findings. Larger multicentric prospective studies are recommended to further validate these observations.

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Tables

Table 1: Distribution of study population by first-trimester BMI category

BMI Category	Number (n=130)	Percentage
Underweight (<18.5 kg/m²)	16	12.3
Normal (18.5-24.9 kg/m²)	68	52.3
Overweight (25.0-29.9 kg/m²)	36	27.7
Obese (≥30 kg/m²)	10	7.7

Table 2: Distribution of study population by gestational weight gain category

GWG Category	Number (n=130)	Percentage
Inadequate	80	61.5
Adequate	45	34.6
Excessive	5	3.8

Table 3: Association of first-trimester BMI with birth weight for gestational age

BMI Category	SGA (n=53)	AGA (n=68)	LGA (n=9)	Total
Underweight	8 (50.0%)	7 (43.8%)	1 (6.3%)	16
Normal	42 (61.8%)	25 (36.8%)	1 (1.5%)	68
Overweight	2 (5.6%)	31 (86.1%)	3 (8.3%)	36
Obese	1 (10.0%)	5 (50.0%)	4 (40.0%)	10

Table 4: Association of gestational weight gain with birth weight for gestational age

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GWG Category	SGA (n=53)	AGA (n=68)	LGA (n=9)	Total
Inadequate	49 (61.3%)	30 (37.5%)	1 (1.3%)	80
Adequate	4 (8.9%)	37 (82.2%)	4 (8.9%)	45
Excessive	0 (0.0%)	1 (20.0%)	4 (80.0%)	5

Figures

Figure 1: Distribution of study participants by first-trimester BMI category (n= 130)

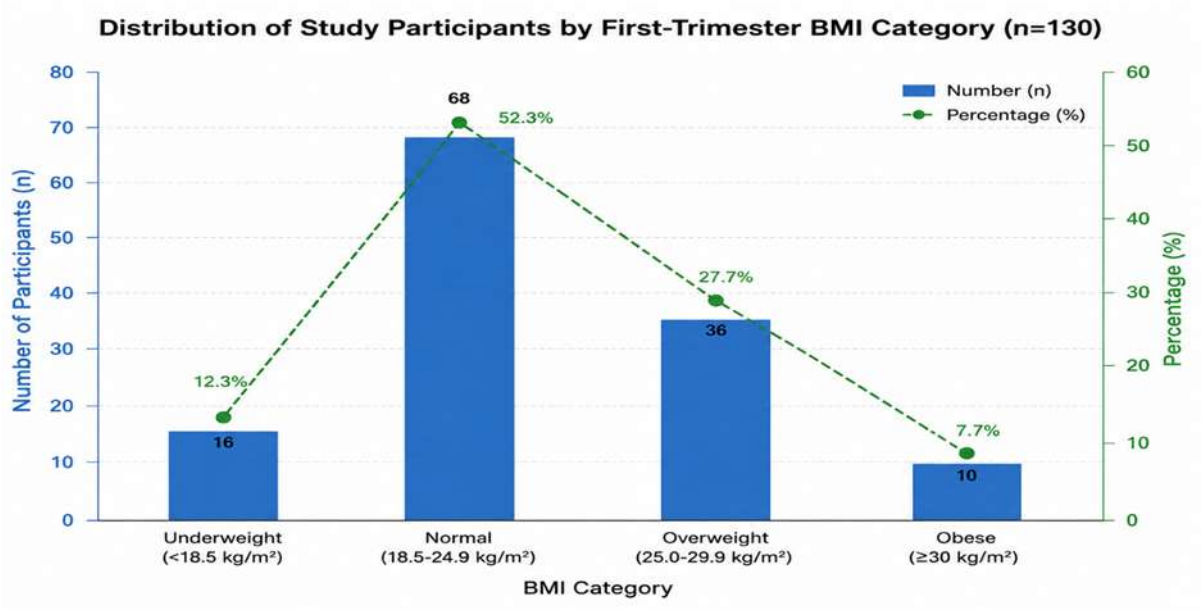

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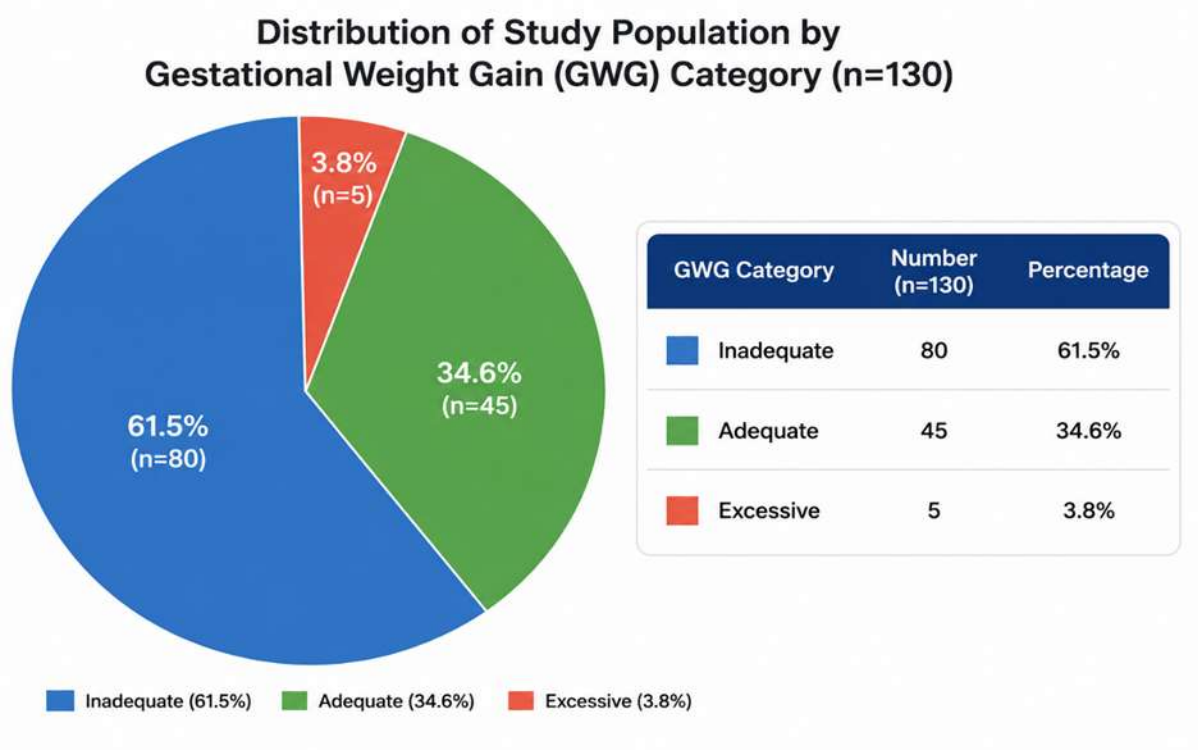
Figure 2: Distribution of study population by gestational weight gain category



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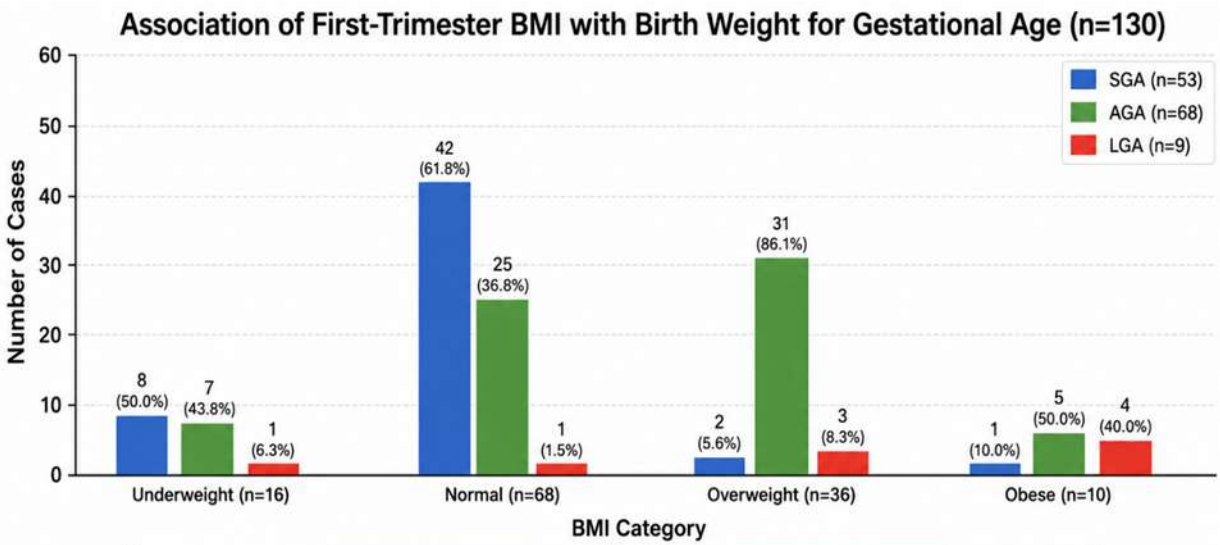

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$\chi^2 = 51.035$; $p < 0.001$

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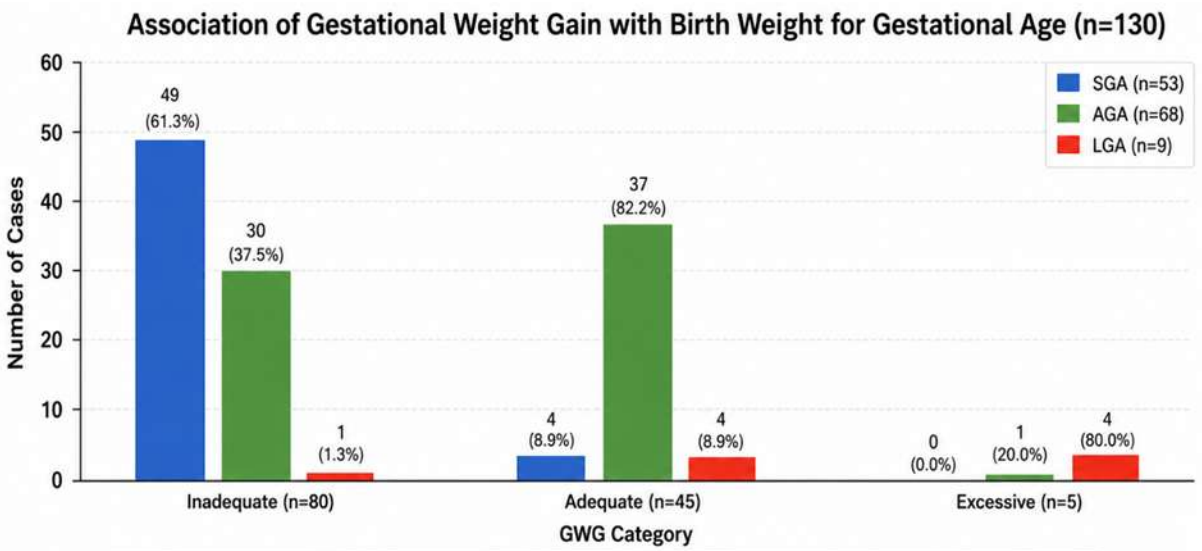
Figure 4: Association of gestational weight gain with birth weight for gestational age



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Adequate	4 (8.9%)	37 (82.2%)	4 (8.9%)	45
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