Original Article

Gestational weight gain and body mass index in Asian Indian women: Impact of timing and amount on fetomaternal outcomes

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Abstract

Background: The aim of the study was to describe pre-pregnancy body mass index (BMI), total gestational weight gain (TGWG), and trimester-specific gestational weight gain (TSGWG) among Asian Indians and examine their association with adverse fetomaternal outcomes (AFMO). **Methods:** Using a prospective cohort study design, 557 pregnant women were recruited in the first trimester and followed up until delivery. Maternal BMI, TGWG and TSGWG were assessed and categorised according to the World Health Organisation (WHO) Asia Pacific BMI guidelines and the Institute of Medicine (IOM) recommendations, respectively. Maternal clinical characteristics and pregnancy and neonatal outcomes were assessed to predict AFMO. Logistic regression models in univariate and multivariate analysis were performed to estimate the odds ratios (OR) and 95% confidence intervals (CI). **Results:** The median BMI was 23.5 kg/m^2. Moreover, 24.6% were overweight and 31.2% were obese, according to WHO Asia Pacific BMI cut points. The mean TGWG was 10.8 ± 1.9 kg and the mean TSGWG in the first, second and third trimesters were 1.7 ± 0.7 kg, 4.3 ± 1.1 kg and 4.8 ± 1.2 kg, respectively. We found a significant association of BMI, TGWG and TSGWG with various AFMO. Furthermore, excess third-trimester GWG has been demonstrated as a predictor of adverse maternal outcomes like hypertension and gestational diabetes mellitus. **Conclusions:** Our study reinforces the importance of optimal BMI and TGWG and further emphasises on assessment of TSGWG, which allows for early diagnosis of weight deviations, when prompt interventions can still improve pregnancy outcomes. We also suggest the adoption of BMI categories and GWG recommendations, specific to the socio-demographic characteristics of the population, to optimise the prevention, early diagnosis, and timely management of AFMO.

Keywords: Body mass index, fetomaternal outcomes, gestational weight gain, obesity, pregnancy

Introduction

Overweight and obesity are widespread in almost every population in the world and are increasing exponentially in developing countries.[1,2] India is going through a double trouble of persistent problems of undernutrition alongside an escalating rise in overweight and obesity.[2]

Maternal obesity is associated with an increased risk of poor pregnancy outcomes. In addition, inappropriate gestational weight gain (GWG) can have deleterious short- and long-term effects on the health of both the mother and the infant. Various studies done in the past have shown an association between body mass index (BMI) and total GWG (TGWG) with adverse fetomaternal outcomes (AFMO)[3,4] but the majority report inconsistent results. TGWG although provides an enduring

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goal for pregnant women and is a good monitoring tool for prenatal health-care providers, fails to assess weight gain patterns throughout pregnancy and its possible impact on AFMO. Assessment of trimester-specific GWG (TSGWG), on the other hand, helps in recognising the adequacy of GWG early on, when intervention is still possible and can benefit in improving maternal and foetal outcomes. Thus, researchers have started evaluating the impact of timing and the amount of GWG on pregnancy outcomes.[5-8] But due to fewer such studies, with relatively small sample sizes and nonrepresentative populations, it is still doubtful whether there are critical windows in pregnancy when inappropriate GWG may have a larger impact and which weight gain trajectories most strongly influence outcome measures.

In 2009, the Institute of Medicine (IOM) released revised GWG guidelines based on pre-pregnancy BMI.[9] Their generalised adoption is impossible as they are based primarily on Western World Health Organisation (WHO) BMI cut-offs and IOM itself later notified that their guidelines were grounded mainly on primigravidas of high social status and sedentary lifestyle.[10] There are conflicting reports in the literature regarding the suitability of IOM recommendations for the Asian population, with some supporting[11] and others opposing.[12] Researchers have therefore suggested the use of different GWG recommendations for different races and ethnicities.[13] Moreover, Asian BMI cut-offs differ from the WHO BMI classification recommended for the West.[14] Few investigators have provided GWG recommendations for Asians as well,[15] but the data available is sparse and insufficient to prove them conclusively. There have been very few studies that have looked at the applicability of the IOM guidelines to Indian pregnant women,[16,17] and till now no national GWG recommendations exist. Furthermore, to the best of our knowledge, no study has been conducted among the Indian population that can relate TSGWG and AFMO across different BMI categories.

Knowledge regarding appropriate BMI and GWG is essential not only for obstetricians but also for primary care physicians, as it allows for better risk assessment, monitoring, and management of pregnancies, promoting healthier outcomes and ultimately reducing the risk of chronic diseases later in life for both the mother and the child.

Hence, we sought to describe BMI, TGWG and TSGWG among our Indian prenatal cohort, using WHO Asia Pacific BMI categories and to determine whether these GWG exposures were associated with AFMO.

Materials and Methods

Study design and patients

This was a prospective observational cohort study of pregnant women who visited us between January 2019 and December 2022. With a yearly turnover of around 7,000 deliveries, our institution is a government-run tertiary medical facility that caters to pregnant women in Northern India. After obtaining clearance from the Institutional Ethical Committee, 1,169 pregnant women of Indian origin, ≥18 and <40 years of age, with confirmed singleton intrauterine pregnancy, and willing to comply with the study protocol were recruited. All participants provided written informed consent for participation in the study. Women who did not have documented proof of their weight and height recorded in the early first trimester, at any health facility were excluded. Women with multiple gestations, chronic hypertension, pre-existing diabetes or hypothyroidism were also excluded. After applying exclusion criteria and disregarding those who aborted or were lost to follow-up, a final analytic sample of 557 mother-infant pairs was assessed [Figure 1].

Data collection

A predesigned, standardised questionnaire was used for recording the patient's socio-demographic and clinical information. The height and weight of study participants were measured according to the standard protocol by trained staff at the first antenatal visit and then at scheduled visits throughout pregnancy. Pre-pregnancy BMI was calculated with the first measured weight and height at ≤10 weeks gestation, based on Fattah *et al.*[18] recommendations. TGWG was calculated by subtracting the maternal first recorded antenatal weight from the final weight before delivery. We calculated first-trimester weight gain [1TrWG] as the weight difference between the early pregnancy and 13 gestational weeks, second-trimester weight gain [2TrWG] as the weight change from 13 weeks to 27 weeks, and third-trimester weight gain [3TrWG] as the weight change from 27 weeks to the day of delivery. Maternal pre-pregnancy

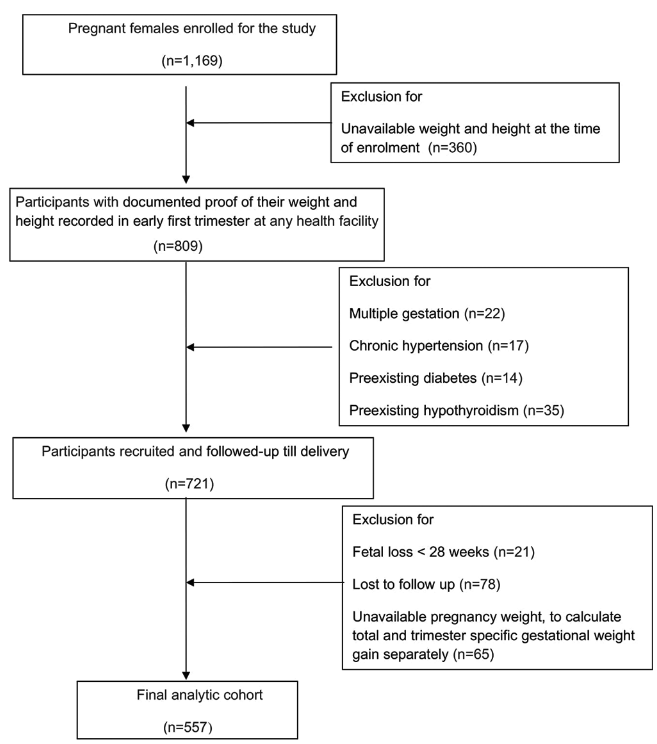

Figure 1: Subject recruitment flow chart

BMI and GWG were categorised according to the WHO Asia Pacific BMI guidelines and the IOM recommendations, respectively.

Follow-up

Subjects were followed up until delivery, to record fetomaternal outcomes. The outcomes assessed included preterm delivery (PTD), premature rupture of membranes (PROM), polyhydramnios, foetal growth restriction (FGR), hypertensive disorders of pregnancy (HDP), gestational diabetes mellitus (GDM), intrahepatic cholestasis of pregnancy (IHCP), induction of labour (IOL), caesarean section (CS), postpartum haemorrhage (PPH), shoulder dystocia (SD), operative vaginal delivery (OVD), baby weight, gender, five-minute Apgar score, low birth weight (LBW), large for gestational age (LGA), respiratory distress syndrome (RDS) and neonatal intensive care unit (NICU) admission. All outcome measures were defined as per the standard recommended definitions.

Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were done, showing proportions and the mean ± standard deviation. Chi-square test was applied to assess the statistical association between BMI categories and GWG status categorised as inadequate, adequate or excessive. TGWG and TSGWG were categorised as excessive and non-excessive as per IOM recommendations. The risk of AFMO due to excessive GWG was assessed by applying univariate regression analysis with non-excessive GWG status as a reference. Multivariate regression analysis of the risk of AFMO was done by taking pre-pregnancy BMI, maternal age, occupation, parity and gestational age at delivery as covariates. The risk estimation is reported as an odds ratio (OR) with a 95% confidence interval (95% CI). Two-sided *P* values of <0.05 were considered to be statistically significant.

Results

Socio-demographic characteristics

The mean age of the study population was 25.05 (3.8) years. The median value of BMI was 23.5 kg/m^2 (interquartile range: 4.2), with 24.6% being overweight and 31.2% obese. The mean TGWG was 10.8 ± 1.9 kg. The mean TSGWG was 1.7 ± 0.7 kg, 4.3 ± 1.1 kg and 4.8 ± 1.2 kg in the first, second and third trimesters, respectively. Maternal socio-demographic characteristics with respect to GWG are represented in Table 1. A statistically significant difference was noted for literacy status and occupation.

Association between maternal BMI categories and GWG

Table 2 shows the distribution of TGWG and TSGWG, stratified by BMI status. Moreover, 20.6% of women had inadequate, 46.0% had adequate and 33.4% had excess TGWG as per the IOM recommendations. When stratified according to BMI, a significant association was found between BMI category and TGWG, with the majority of underweight women gaining inadequate and obese women gaining excess TGWG. On further analysing GWG adequacy in different trimesters, we did not find a significant association between BMI and 1TrWG, but a statistically significant association was found for 2TrWG and 3TrWG, with the majority of underweight females having inadequate GWG and obese females having excess GWG.

Association between AFMO and excess BMI, TGWG and TSGWG

Overall, 76.7% (427/557) of study participants experienced some or other adverse maternal outcomes [Figure 2]. Regarding adverse

Table 1: Maternal socio-demographic characteristics, stratified by GWG (*n*=557)

Socio-demographic characteristics	*n* (%)	TGWG (kg)	Gestational 1TrWG (kg)	Weight 2TrWG (kg)	Gain 3TrWG (kg)
Maternal age group (years)					
18–<25	265 (47.6)	10.7 (1.9)	1.7 (0.7)	4.3 (1.1)	4.7 (1.1)
25–<30	205 (36.8)	10.9 (2.0)	1.8 (0.7)	4.3 (1.0)	4.9 (1.2)
30–<35	70 (12.6)	11.2 (2.2)	1.9 (0.7)	4.3 (1.1)	5.0 (1.3)
≥35	17 (3.1)	10.6 (2.1)	1.9 (0.7)	4.2 (1.5)	4.5 (1.0)
Literacy status					
Illiterate	153 (27.5)	10.5 (1.7)*	1.7 (0.6)	4.1 (0.9)*	4.7 (1.1)
Literate	404 (72.5)	11.0 (2.1)*	1.8 (0.7)	4.3 (1.2)*	4.8 (1.2)
Occupation					
Housework	525 (94.3)	10.9 (2.0)*	1.8 (0.7)	4.3 (1.1)*	4.8 (1.2)*
Working	32 (5.7)	9.6 (2.0)*	1.8 (0.7)	3.8 (1.1)*	4.4 (1.0)*
Parity					
Primi	245 (44.0)	10.8 (1.9)	1.8 (0.7)	4.2 (1.1)	4.8 (1.2)
Multigravida (1–4)	262 (47.0)	10.9 (2.1)	1.7 (0.7)	4.3 (1.1)	4.8 (1.3)
Grandmultipara (>5)	50 (9.0)	10.6 (1.6)	1.8 (0.6)	4.1 (1.1)	4.7 (0.9)
Place of residence					
Urban	368 (66.1)	10.9 (2.0)	1.8 (0.7)	4.3 (1.1)	4.8 (1.2)
Rural	189 (33.9)	9.6 (2.0)	1.8 (0.6)	3.8 (1.1)	4.4 (1.0)

*Statistically significant, *P*<0.05 (independent sample *t*-test). TGWG: total gestational weight gain, 1TrWG: first-trimester weight gain, 2TrWG: second-trimester weight gain, 3TrWG: third-trimester weight gain

Table 2: Distribution of TGWG and TSGWG, stratified by BMI status, among study participants (*n*=557)

GWG	Total *n*=557	Underweight *n*=31	BMI normal weight *n*=215	Overweight *n*=137	Obese *n*=174
IOM recommended range[$] (kg)		12.5-18	11.5-16	7-11.5	5-9
TGWG, mean (SD)	10.8 (1.9)	11.0 (1.7)	11.6 (2.3)	10.0 (1.6)	10.5 (1.6)
Inadequate, *n* (%)*	115 (20.6)	22 (71.0)	93 (43.3)	0 (0.0)	0 (0.0)
Adequate, *n* (%)*	256 (46.0)	9 (29.0)	113 (52.6)	109 (79.6)	25 (14.4)
Excessive, *n* (%)*	186 (33.4)	0 (0.0)	9 (4.2)	28 (20.4)	149 (85.6)
1TrWG, mean (SD)	1.7 (0.7)	1.6 (0.7)	1.7 (0.7)	1.6 (0.6)	1.9 (0.7)
Inadequate, *n* (%)	15 (2.7)	2 (6.5)	4 (1.9)	2 (1.5)	7 (4.0)
Adequate, *n* (%)	456 (81.9)	25 (80.6)	182 (84.7)	121 (88.3)	128 (73.6)
Excessive, *n* (%)	86 (15.4)	4 (12.9)	29 (13.5)	14 (10.2)	39 (22.4)
2TrWG, mean (SD)	4.3 (1.1)	4.6 (1.1)	4.7 (1.1)	3.8 (0.9)	4.0 (1.0)
Inadequate, *n* (%)*	199 (35.7)	28 (90.3)	124 (57.7)	41 (29.9)	6 (3.40
Adequate, *n* (%)*	229 (41.1)	3 (9.7)	88 (40.9)	71 (51.8)	67 (38.5)
Excessive, *n* (%)*	129 (23.2)	0 (0.0)	3 (1.4)	25 (18.2)	101 (58.0)
3TrWG, mean (SD)	4.8 (1.2)	4.8 (1.1)	5.1 (1.3)	4.6 (1.0)	4.6 (1.1)
Inadequate, *n* (%)*	108 (19.4)	28 (90.3)	77 (35.8)	3 (2.2)	0 (0.0)
Adequate, *n* (%)*	225 (40.4)	3 (9.7)	124 (57.7)	69 (50.4)	29 (16.7)
Excessive, *n* (%)*	224 (40.2)	0 (0.0)	14 (6.5)	65 (47.4)	145 (83.3)

*Statistically significant, $P<0.05$ (Chi-square test). [$]Institute of Medicine, 2009 recommendations. BMI: body mass index, TGWG: total gestational weight gain, TSGWG: trimester specific gestational weight gain, 1TrWG: first-trimester weight gain, 2TrWG: second-trimester weight gain, 3TrWG: third-trimester weight gain, SD: standard deviation

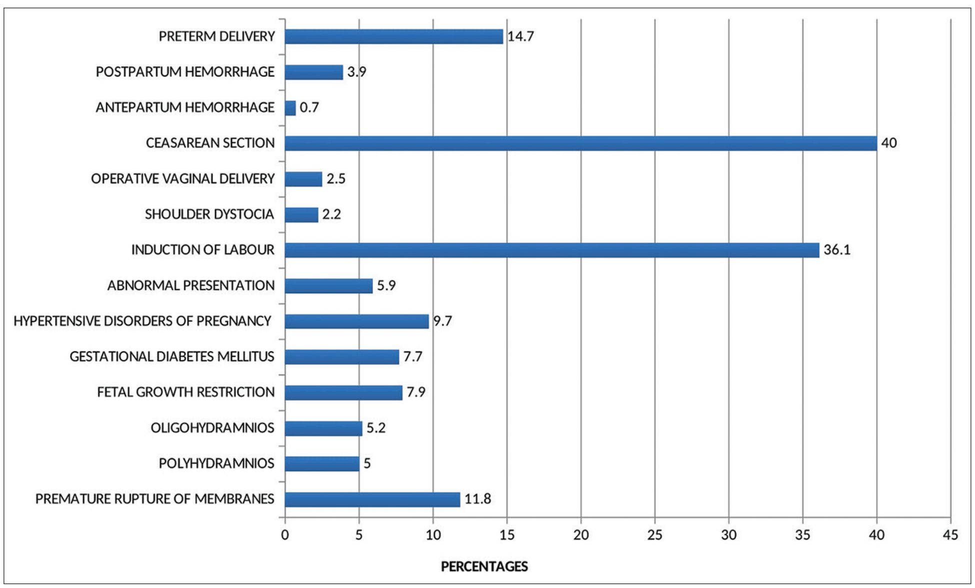

Figure 2: Distribution of maternal complications among study participants

neonatal outcomes, 13.8% (77/557) had LBW, 5.4% (30/557) had LGA, whereas 19% (106/557) had some or other neonatal complications like RDS, congenital anomalies or NICU admission.

Relationships between excess BMI and GWG and AFMO, assessed through univariate and multivariate regression predictive models are represented in Tables 3 and 4, respectively. We also observed a higher pre-pregnancy BMI to significantly increase the risk of polyhydramnios ($P = 0.003$), GDM ($P = 0.000$), HDP ($P = 0.000$), OVD ($P = 0.009$), CS ($P = 0.000$) and LGA babies ($P = 0.000$) but had a protective association with PTD (OR: 0.9; 95% CI: 0.8–0.9). Women with excess TGWG were significantly more likely to have polyhydramnios ($P = 0.003$), HDP ($P = 0.000$), SD ($P = 0.005$), CS ($P = 0.044$) and LGA babies ($P = 0.012$).

When the risk of AFMO was sought due to excessive TSGWG, we found excess 1TrWG to increase the risk of PTD ($P = 0.013$). For women with excess 2TrWG, the risk was increased for PTD ($P = 0.014$), SD ($P = 0.030$), PPH ($P = 0.011$) and LGA ($P = 0.027$). Excess 3TrWG increased the risk of GDM ($P = 0.000$), HDP ($P = 0.002$), CS ($P = 0.004$) and NICU admission ($P = 0.000$).

Excess 3TrWG was found to be protective for LBW but in adjusted models, the effect was not statistically significant. Further, we did not observe a significant association with any other studied variables.

Table 3: Univariate regression analysis, predicting the risk of AFMO due to excess pre-pregnancy BMI, TGWG and TSGWG (*n*=557)

	Pre-pregnancy BMI		TGWG		1TrWG		2TrWG		3TrWG	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Maternal complications										
Preterm delivery	0.9 (0.8–0.9)	0.000	0.6 (0.4–1.0)	0.063	1.4 (0.8–2.6)	0.271	1.1 (0.6–1.9)	0.775	0.4 (0.2–0.7)	0.001
PROM	1.0 (0.9–1.1)	0.369	1.1 (0.6–1.8)	0.789	0.4 (0.7–2.7)	0.310	1.0 (0.5–1.8)	0.929	1.1 (0.7–1.9)	0.697
Polyhydramnios	1.1 (1.1–1.2)	0.004	5.5 (2.4–12.7)	0.000	0.4 (0.1–1.8)	0.408	2.6 (1.2–5.7)	0.014	3.3 (1.5–7.5)	0.004
Oligohydramnios	0.9 (0.8–1.0)	0.128	0.7 (0.3–1.7)	0.497	1.8 (0.7–4.8)	0.189	0.9 (0.3–2.2)	0.746	0.4 (0.1–0.9)	0.034
FGR	0.9 (0.8–1.0)	0.182	0.7 (0.4–1.5)	0.371	0.9 (0.4–2.1)	0.730	0.4 (0.2–1.0)	0.061	0.6 (0.3–1.2)	0.134
GDM	1.2 (1.1–1.3)	0.000	2.7 (1.5–5.2)	0.002	1.1 (0.5–2.5)	0.874	3.6 (1.9–6.8)	0.000	2.7 (1.4–5.2)	0.002
HDP	1.2 (1.1–1.3)	0.000	5.7 (3.1–10.5)	0.000	1.5 (0.7–3.0)	0.294	1.8 (1.0–3.2)	0.065	3.7 (2.0–6.7)	0.000
Abnormal presentation	1.1 (1.0–1.2)	0.011	2.2 (1.1–4.5)	0.026	1.5 (0.6–3.6)	0.347	1.3 (0.6–2.8)	0.564	1.9 (0.9–3.8)	0.088
IOL	1.0 (1.0–1.1)	0.725	1.4 (0.9–2.0)	0.097	1.2 (0.7–1.9)	0.469	0.9 (90.6–1.4)	0.594	1.7 (1.2–2.4)	0.004
SD	1.1 (0.9–1.2)	0.274	6.2 (1.7–23.3)	0.007	2.8 (0.8–9.6)	0.096	4.9 (1.5–15.6)	0.008	7.7 (1.7–35.6)	0.009
OVD	1.2 (1.0–1.3)	0.015	2.7 (0.9–8.0)	0.066	0.9 (0.2–4.1)	0.904	1.9 (0.6–5.7)	0.267	2.7 (0.9–8.3)	0.074
CS	1.1 (1.1–1.2)	0.000	2.4 (1.7–3.5)	0.000	1.7 (1.1–2.7)	0.023	1.6 (1.1–2.4)	0.020	2.1 (1.5–3.0)	0.000
PPH	1.0 (0.9–1.1)	0.765	1.4 (0.6–3.3)	0.448	0.3 (0.0–1.9)	0.181	2.9 (1.2–6.9)	0.015	2.7 (1.1–6.6)	0.027
Neonatal complications										
LBW	0.9 (0.8–1.0)	0.004	0.5 (0.3–0.9)	0.025	1.0 (0.6–2.2)	0.706	0.9 (0.5–1.5)	0.594	0.4 (0.2–0.7)	0.002
LGA	1.2 (1.1–1.3)	0.000	7.3 (3.1–17.4)	0.000	2.5 (1.1–5.7)	0.028	4.8 (2.3–10.3)	0.000	4.4 (1.9–10.1)	0.000
Poor Apgar score at 5 min (≤7)	1.0 (0.9–1.0)	0.173	0.9 (0.5–1.7)	0.748	1.0 (0.4–2.3)	0.982	1.2 (0.6–2.6)	0.601	0.7 (0.4–1.3)	0.218
Any of the complications* (RDS, NICU, CA, FD)	1.0 (1.0–1.1)	0.695	1.1 (0.7–1.7)	0.656	0.9 (0.5–1.6)	0.068	1.4 (0.9–2.3)	0.164	1.0 (0.6–1.5)	0.890

*RDS: respiratory distress syndrome, NICU: neonatal intensive care unit, CA: any congenital anomaly and FD: foetal distress. BMI: body mass index, TGWG: total gestational weight gain, TSGWG: trimester specific gestational weight gain, 1TrWG: first-trimester weight gain, 2TrWG: second-trimester weight gain, 3TrWG: third-trimester weight gain

Table 4: Multivariate regression analysis, predicting the risk of AFMO due to excess pre-pregnancy BMI*, TGWG and TSGWG** (*n*=557)**

	Pre-pregnancy BMI		TGWG		1TrWG		2TrWG		3TrWG	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Maternal complications										
Preterm delivery	0.9 (0.8–1.1)	0.241	12.2 (1.9–77.5)	0.008	5.9 (1.5–23.4)	0.013	11.1 (1.8–68.8)	0.009	0.9 (0.7–1.1)	0.321
PROM	1.0 (1.0–1.1)	0.330	1.3 (0.6–2.7)	0.515	1.5 (0.7–2.9)	0.265	1.0 (0.8–2.0)	0.921	1.0 (0.9–1.1)	0.914
Polyhydramnios	1.2 (1.1–1.3)	0.003	5.1 (1.8–14.8)	0.003	0.3 (0.1–1.3)	0.108	1.7 (0.7–4.0)	0.261	1.1 (1.0–1.2)	0.097
Oligohydramnios	0.9 (0.8–1.0)	0.172	1.3 (0.4–4.0)	0.630	2.1 (0.8–5.2)	0.116	1.3 (0.4–3.8)	0.664	1.0 (0.9–1.1)	0.714
FGR	0.9 (0.8–1.0)	0.108	0.9 (0.4–2.3)	0.855	0.9 (0.4–2.3)	0.875	0.4 (0.1–1.2)	0.093	1.0 (0.9–1.1)	0.589
GDM	1.2 (1.1–1.3)	0.000	1.0 (0.4–2.2)	0.983	0.7 (0.3–1.7)	0.370	2.0 (1.0–4.2)	0.050	1.2 (1.1–1.3)	0.000
HDP	1.3 (1.2–1.4)	0.000	4.2 (1.9–9.3)	0.000	1.2 (0.6–2.8)	0.610	0.9 (0.4–1.7)	0.654	1.1 (1.1–1.2)	0.002
Abnormal presentation	1.1 (1.0–1.2)	0.014	1.4 (0.6–3.4)	0.492	1.2 (0.5–3.0)	0.694	0.7 (0.3–1.8)	0.506	1.1 (1.0–1.2)	0.049
IOL	1.0 (1.0–1.2)	0.655	1.6 (1.0–2.6)	0.048	1.2 (0.7–1.9)	0.484	0.8 (0.5–1.3)	0.404	1.0 (0.9–1.0)	0.099
SD	1.2 (1.0–1.4)	0.056	5.5 (2.3–106.1)	0.005	2.8 (0.7–10.5)	0.132	5.8 (1.2–28.7)	0.030	0.9 (0.7–1.1)	0.233
OVD	1.2 (1.0–1.3)	0.009	1.7 (0.4–6.5)	0.463	0.7 (0.2–3.4)	0.663	1.1 (0.3–3.9)	0.881	1.1 (1.0–1.3)	0.053
CS	1.1 (1.1–1.2)	0.000	1.6 (1.0–2.6)	0.044	1.5 (0.9–2.4)	0.117	1.0 (0.6–1.6)	0.987	1.1 (1.0–1.2)	0.004
PPH	1.0 (0.9–1.2)	0.519	1.6 (0.5–5.1)	0.421	0.2 (0.0–1.8)	0.164	3.9 (1.4–10.9)	0.011	0.9 (0.8–1.1)	0.231
Neonatal complications										
LBW	0.9 (0.9–1.0)	0.240	0.9 (0.3–2.6)	0.902	1.9 (0.8–4.4)	0.157	1.3 (0.5–3.5)	0.558	1.0 (0.9–1.1)	0.763
LGA	1.3 (1.2–1.4)	0.000	3.9 (1.3–11.1)	0.012	1.9 (0.8–4.8)	0.157	2.7 (1.1–6.6)	0.027	1.0 (1.0–1.1)	0.372
Poor Apgar score at 5 min (≤7)	1.0 (0.9–1.1)	0.475	1.2 (0.5–2.8)	0.618	1.0 (0.4–2.4)	0.981	1.6 (0.7–3.7)	0.278	1.0 (0.9–1.1)	0.446
Any of the other complications*** (RDS, NICU, CA, FD)	1.0 (1.0–1.1)	0.184	1.1 (0.6–2.1)	0.740	0.8 (0.4–1.7)	0.639	1.5 (0.8–2.7)	0.195	1.2 (1.1–1.4)	0.000

*Models for pre-pregnancy BMI adjusted for maternal age, parity, gestational age at delivery maternal occupation and TGWG. **Models for TGWG, 1TrWG, 2TrWG, and 3TrWG adjusted for maternal age, parity, pre-pregnancy BMI, gestational age at delivery and maternal occupation. ***RDS: respiratory distress syndrome, NICU: neonatal intensive care unit, CA: any congenital anomaly and FD: foetal distress. BMI: body mass index, TGWG: total gestational weight gain, TSGWG: trimester specific gestational weight gain, 1TrWG: first-trimester weight gain, 2TrWG: second-trimester weight gain, 3TrWG: third-trimester weight gain

Discussion

The prevalence of obesity among study participants was 31%, which is higher than most Indian studies.[17] One probable reason can be the use of an Asian cut-off for BMI, which has not been used in many other studies. Bhavadharini B *et al.*[16] who used similar BMI cut-offs, also found a higher prevalence of obesity in their study participants. The mean TGWG in this study was 10.84 ± 1.98 kg, which is lower than the optimal GWG recommended by the IOM for pregnant women with normal pre-gestational BMI[9] but almost similar to those reported from the Indian population.[17] The average TSGWG in the present study is within the normal range recommended by the IOM.[9] The present study establishes the association of pre-pregnancy BMI and TGWG with AFMO. In addition, TSGWG has been demonstrated as a predictor of AFMO in this study. Regarding AFMO analysis, the majority of previously published studies have assessed their relationship with TGWG and only a few have explored its association with TSGWG.

Hypertensive disorders of pregnancy

We found higher pre-pregnancy BMI, TGWG and 3TrWG to be positively associated with the HDP. Similar to our results, Zhang X *et al.*[19] and I. Gonzalez-Ballano *et al.*[8] also found an increased risk of excess GWG in all trimesters with HDP but the highest risk is with third-trimester GWG.

Gestational diabetes mellitus

GDM was found to have a statistically significant association with BMI and 3TrWG in the present study. There are conflicting results in the literature regarding the association of TSGWG with GDM. Few studies have demonstrated a negative relationship between excess 3TrWG with GDM,[8] few showed a positive association between 1TrWG and 2TrWG and GDM,[20] while some found no significant association between TSGWG with GDM.[19,21]

Caesarean section

We found a significant positive association between pre-pregnancy BMI, TGWG and 3TrWG with CS. Our findings are in accordance with those of Zhang X[19] and Drehmer M *et al.*[5] Studies have suggested that excessive 3TrWG might exacerbate the deposition of pelvic soft tissue, resulting in a reduced pelvic area and may worsen pelvic inflammatory changes, making vaginal delivery more challenging.[19,22]

Preterm delivery

To date, the findings on the link between BMI, GWG and PTD have been inconsistent, and the biochemical mechanism underlying the effect of GWG time on preterm birth (PTB) is unknown. It is plausible to believe that the timing of excessive GWG is essential in predicting PTD. In our study, high pre-pregnancy BMI and 3TrWG were found to have a protective relationship with PTD on univariate analysis, but in adjusted models, we found excess TGWG, 1TrWG and 2TrWG to be risk factors for PTD. Our findings are partly supported by studies from Peru[23] and China,[7] but are contradictory to many studies done in the past. The majority of them were conducted in high-income nations with distinct racial, cultural, and socioeconomic characteristics rather than in low- and middle-income countries, thus their generalisation is not feasible. Besides, we have used different BMI categories in our study and have not included types of PTD like early or late, spontaneous or induced and associated with PROM or not.

Based on our findings, we hypothesise that besides obesity, excess TGWG in general and 3TrWG in particular can be considered a predictor of various adverse maternal outcomes like HDP, GDM and CS.

Neonatal outcomes

The relationship between neonatal birth weight with BMI and TGWG has been well studied.[4,24,25] Several studies have demonstrated a positive association between high pre-gestational BMI and/or TGWG with LGA neonates[24] and low BMI and/or TGWG with SGA.[25] However, only a few studies have examined the association of TSGWG with neonatal birthweight and other foetal outcomes.[6,8] We found a positive relationship between excess BMI, TGWG and 2TrWG with LGA neonates. Excess TGWG and 3TrWG were found to be protective for SGA but in adjusted models, these effects were not found to be statistically significant.

We also found a positive association of excess 3TrWG and a negative association of excess 1TrWG with other neonatal complications like foetal distress, a poor Apgar score at 5 minutes, RDS and NICU admission.

Our study has several strengths like prospective cohort study design, rigorous collection and maintenance of records, the availability of measured weight and height as well as ability to assess GWG in all three trimesters. This is one of the first studies from India to study AFMO in relation to WHO Asia Pacific BMI and TSGWG. However, a few limitations need to be highlighted. Firstly, data on potential confounders, such as diet and physical activity, were not collected, so we could not exclude their confounding effects or confounding from other unmeasured covariates. Secondly, a relatively small sample size limited our ability to perform detailed subgroup analyses. Furthermore, using early-pregnancy BMI as the approximation of pre-pregnancy BMI might lead to some women being misclassified, although such misclassification would probably be small. BMI should ideally be calculated using pre-pregnancy weight. However, as evidenced by previous research, data on pre-pregnancy BMI is rarely available. Some studies have relied on self-reported pre-pregnancy weight, which is subject to recall error and can lead to under- or overestimation can be unreliable at times. Weight recorded in early pregnancy was the only practical way to get trustworthy information in our investigation. Finally, the study was conducted at an urban antenatal centre, and although it caters to patients with a wide mix of socio-demographics but still its generalizability to rural or to the whole of India must be done with caution.

Conclusion

The present study comprehensively evaluated pre-pregnancy BMI and GWG among Indian women and reinforced their potential importance for better fetomaternal outcomes. Our results contribute to the growing body of evidence that the amount and timing of GWG have a varying impact on pregnancy outcomes. We therefore suggest that assessing TGWG alone is insufficient, and evaluation of TSGWG should also be considered as it allows for early detection of weight deviations in pregnancy when timely interventions can still improve pregnancy outcomes.

Our findings further emphasise the significance of adapting preconception and antenatal care tailored to the BMI categories and GWG recommendations, specific to the socio-demographic characteristics of the population. This will provide more appropriate clinical surveillance to optimise the prevention, early diagnosis, and timely management of AFMO and will ultimately contribute to improving the current and long-term health of both the women and their offspring.

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Conflicts of interest

There are no conflicts of interest.

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