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Associations of Gestational Weight Gain with Perinatal Outcomes in Western Brazilian Amazon

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Abstract

Objective To investigate the association between gestational weight gain (GWG) and perinatal outcomes in pregnant Amazonian women.

Methods Data from 1305 mother–child pairs from the MINA-Brazil population-based birth cohort study were used. GWG was classified according to two methods, the Institute of Medicine (IOM) guidelines and INTERGROWTH-21st standards. Poisson and linear regression analyses were conducted to evaluate associations with perinatal outcomes.

Results Following IOM guidelines (n = 1305), the rates of insufficient and excessive GWG were found to be similar (32%). Excessive GWG was associated with higher new-born birthweight (BW) z-scores; increased risks of macrosomia, large for gestational age (LGA), and caesarean delivery; and lower risks of low birthweight (LBW) and being small for gestational age (SGA). Insufficient GWG was associated with lower new-born BW z-scores. Among women with normal pre-pregnancy body mass indices (BMIs, n = 658), inappropriate GWG was high following both methods (IOM: 41.2% insufficient, 24.8% excessive; INTERGROWTH-21st: 25.2% below − 1 z-score, 16.9% above 1 z-score). Both methods also indicated that newborns of women with excessive GWG had higher BW z-scores and increased risk of macrosomia and LGA. Women with GWG below the INTERGROWTH-21st standards were more likely to deliver an infant SGA and with lower BW z-scores.

Conclusions Inappropriate GWG remains a health concern irrespective of the method used to classify weight gain. GWG above the recommendations of both methods and below the INTERGROWTH-21st standard was associated with adverse perinatal outcomes. Therefore, INTERGROWTH-21st standards seem to be a better fit for healthy women in this population.

Keywords Gestational weight gain · Guidelines adherence · INTERGROWTH-21st standards · Institute of Medicine · Perinatal outcomes

Significance

What is already known on this subject? Suboptimal gestational weight gain (GWG) may have lasting consequences on maternal and child health. However, no consensus on what constitutes optimal GWG is available in low-income settings where both insufficient and excessive GWG are prevalent.

What does this study adds? GWG above the recommendations of the Institute of Medicine or INTERGROWTH-21st is associated with an increased risk of macrosomia and LGA infants. GWG below the recommendations of INTERGROWTH-21st is associated with an increased risk of SGA infants. Among healthy women INTERGROWTH-21st could better guide ideal GWG.

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Introduction

Maternal undernutrition and obesity are highly prevalent in low-resource settings, and are associated with adverse obstetric outcomes and poor offspring health. The frequency of excessive maternal weight has increased in the last four decades and exceeds the underweight condition across the globe (Black et al., 2013). According to the World Health Organization (WHO), in 2016, 39% and 15% of women older than 18 years worldwide were either overweight or obese, respectively (WHO, 2016). In 2017, Brazil exceeded the median global rates of overweight (> 40%) and obesity (> 20%) among adult women (WHO, 2017).

Maternal nutritional status during gestation is a major determinant of pregnancy outcomes. However, the effect of gestational weight gain (GWG) on pregnancy outcomes varies with the woman's pre-pregnancy nutritional status, commonly expressed as body mass index (BMI, kg/m^2) (Hung & Hsieh, 2016). An inappropriate GWG results in unfavourable consequences for both the pregnant woman and her child (IOM, 2009). As previously reported in a systematic review, pregnant women with suboptimal GWG are more likely to deliver preterm and small for gestational age (SGA) infants, whereas excessive GWG is associated with a higher risk of caesarean delivery, macrosomia, and large for gestational age (LGA) neonates. However, inappropriate GWG was found in 70% of pregnancies in different parts of the world (Goldstein et al., 2017). We have previously reported, using data from a cohort of Amazonian pregnant women, that the weekly GWG measured between the second and third trimesters was inappropriate in 80% of pregnancies (Campos et al., 2019). Although inappropriate pre-pregnancy weight and GWG are potentially modifiable exposure factors, no international consensus regarding what would be a desirable GWG is available (Ohadike et al., 2016). Thus, policies and recommendations for GWG are different throughout the world (Scott et al., 2014).

In 2009, the Institute of Medicine (IOM) issued guidelines for optimal GWG (IOM, 2009), which recommends a weight gain range during pregnancy according to pre-pregnancy BMI categories defined by the WHO. These guidelines were formulated for North American women, in order to improve pregnancy outcomes. Nonetheless, the Brazilian Ministry of Health adopted the IOM recommendations of GWG, combining them with Atalah's curves into prenatal care protocols (Brazil, 2012). In 2016, the International Fetal and Newborn Growth Consortium for the 21st Century (INTERGROWTH-21st) published GWG standards on the basis of gestational age (GA). The INTERGROWTH-21st chart is based on a prospective longitudinal study from eight geographically diverse urban regions, including the city of Pelotas in Brazil (Cheikh Ismail et al., 2016). While this set of standards can guide the development of consistent recommendations on GWG for women with normal pre-pregnancy, its use in the prenatal care routine should be considered only after a better understanding of its applicability in maternal and foetal complications.

Therefore, this study aimed to investigate the association between GWG and perinatal outcomes among pregnant women in the Brazilian Amazon, using the recommendations for defining adequate GWG from both the IOM and INTERGROWTH-21st methods.

Methods

Study Population

This analysis is based on data from the Maternal and Child Health and Nutrition in Acre (MINA-Brazil), a population-based birth cohort in Cruzeiro do Sul, Acre State, Western Brazilian Amazon, as previously described (Cardoso et al., 2020). Briefly, pregnant women admitted for delivery between July 2015 and June 2016 in the maternity ward in the region were invited to participate in the study. Baseline data were collected at enrolment after the study participants provided written informed consent. For teenagers, consent was provided by their caregivers. The current analyses included all the women who delivered a singleton live infant and had available data on pre-pregnancy weight and maternal weight at delivery. All the research procedures were approved by the ethical review board of the School of Public Health, University of São Paulo, Brazil (Number 872.613, 13 November 2014), following the ethical statements of the Declaration of Helsinki.

Data Collection and Procedures

Baseline data were obtained through face-to-face interviews and included maternal age at delivery, self-reported skin colour (white or non-white), maternal schooling (≤ 9 or > 9 years), presence of household assets to generate a wealth index (in tertiles) using a principal component analysis (Filmer & Pritchett, 2001), living with a partner (yes or no), area of residence (rural or urban), parity (primipara or multipara), smoking and/or hypertension during pregnancy (yes or no), gestational malaria (yes or no), prior preterm birth (yes or no), prior caesarean delivery (yes or no), and gestational iron supplementation (yes or no).

Data retrieved from medical records included the number of antenatal care visits (< 6 or ≥ 6 visits), maternal haemoglobin concentration at delivery (Hb, g/L), maternal weight at delivery, type of delivery (vaginal or caesarean section), new-born sex (female or male), GA at delivery (< 37, 37–41, ≥ 42 weeks), and birthweight (BW, g).

Pre-pregnancy weight (kg) and maternal height (m) data were collected from the prenatal cards. Maternal weight at pregnancy onset was based on the measurements taken at the first antenatal care visit, before 14 weeks, or self-reported if the first antenatal visit occurred after the first gestational trimester. In a separate analysis, we found a good agreement between prenatal card records and standardised research measurements for height and pregestational weight (Damasceno et al., 2022).

Pre-pregnancy BMI was computed by dividing pre-pregnancy weight by squared height and subsequently categorised according to WHO standards, as underweight (< 18.5 kg/m^2), normal weight (18.5–24.99 kg/m^2), overweight (25–29.99 kg/m^2), or obese (≥ 30 kg/m^2). For teenage pregnancies (< 19 years), we used the WHO BMI classification as it was found to be a good method for use in Brazilian teenagers compared to the Child Growth Standards (Pinho-Pompeu et al., 2019).

Exposure Variable

The exposure of interest was GWG, which was calculated using the difference between maternal weight at delivery and pre-pregnancy weight, and then classified as insufficient, adequate, or excessive in accordance with the IOM recommendations. For preterm deliveries, adherence to the IOM GWG guidelines was determined by the expected GWG for length of gestation, estimated from the recommended weekly weight gain ranges (IOM, 2009). GWG was standardised into GA-specific z-scores using the INTERGROWTH-21st calculator for women with normal pre-pregnancy BMI and GA < 40 weeks (Intergrowth-21st Project, 2017), and afterwards were grouped into below − 1 z-score, between − 1 to 1 z-score, and above 1 z-score (Jin et al., 2019).

Outcome Variables

The outcomes included maternal Hb and anaemia, caesarean delivery, preterm birth, new-born BW z-score, low BW (LBW), macrosomia, SGA, and LGA. Maternal Hb was determined at delivery using an automated cell counter (SDH-20, Labtest; Lagoa Santa, Brazil) and anaemia was defined as Hb < 110.0 g/L (WHO, 2012). GA at delivery was obtained from the medical records and showed high level of accuracy when compared with ultrasonography estimates (Lourenço et al., 2020). Preterm birth was defined as GA at delivery < 37 weeks. BW was measured by trained maternity staff using a Toledo Junior portable digital scale (Mettler Toledo; Columbus, OH), and categorised into low BW (LBW < 2500 g) or macrosomia (> 4000 g). BW z-scores and percentiles were calculated according to the INTERGROWTH-21st Project (Villar et al., 2014) without the identification of implausible values (WHO, 1995). BW percentiles were categorised into SGA (BW for GA < 10th percentile) or LGA (BW for GA > 90th percentile).

Statistical Analysis

Baseline characteristics of the study participants were examined using proportions (%) for categorical variables and means with standard deviations (SDs) for continuous variables and were compared among the IOM GWG categories using the chi-squared test, Fisher's exact test, or one-way ANOVA. Tests for proportions and Student's *t*-test were used to compare outcome distributions for the corresponding GWG categories between the two methods.

Poisson regression with robust error estimates and linear regression analysis were conducted to estimate the crude and adjusted relative risk (aRR) and β-coefficients with 95% CIs for the relationship between GWG and dichotomic or continuous perinatal outcomes, respectively. We deemed the adequate GWG category and GWG z-scores between − 1 and 1 to be the reference groups. Multivariable analyses were adjusted for potential confounders. When GWG was classified according to the INTERGROWTH-21st standards, the adjusted analyses did not include GA at delivery. Covariates associated with the exposure at P ≤ 0.20 in the crude analysis and based on their conceptual importance with the outcomes were selected. Missing value categories were created to be included in the models. P-values are two tailed and the level of significance was set at P < 0.05.

The association between GWG classification according to IOM guidelines and perinatal outcomes was described among all studied participants. As INTERGROWTH-21st standards are available only for adult normal pre-pregnancy BMI women with GA < 40 weeks, perinatal outcomes were also compared between methods in a subset of the participants. Stata (version 15.1, StataCorp; College Station, TX) was used to perform all the statistical analyses.

Results

Out of 1881 births in the city during the study period, 112 abortions (fetal loss up to the 23rd week of pregnancy) and 16 stillbirths (infant loss after the 23rd weeks of pregnancy) occurred. Of the 1753 live births, 184 refused to participate and 18 were not contacted before hospital discharge. Overall, 1551 women agreed to participate in the MINA-Brazil birth cohort (Fig. 1). Of them, 13 twin pregnancies (26 infants) were not eligible for this analysis. We excluded 220 women with incomplete data on either pre-pregnancy weight or weight at delivery, resulting in 1305 mother–child pairs (85.6% of eligible population) included in the study. When compared the baseline characteristics of the participants included in this analysis with those women excluded due to incomplete data (n = 220), no differences were found in urban area (n = 130). However, the excluded women living in rural area (n = 90) had lower mean values for schooling

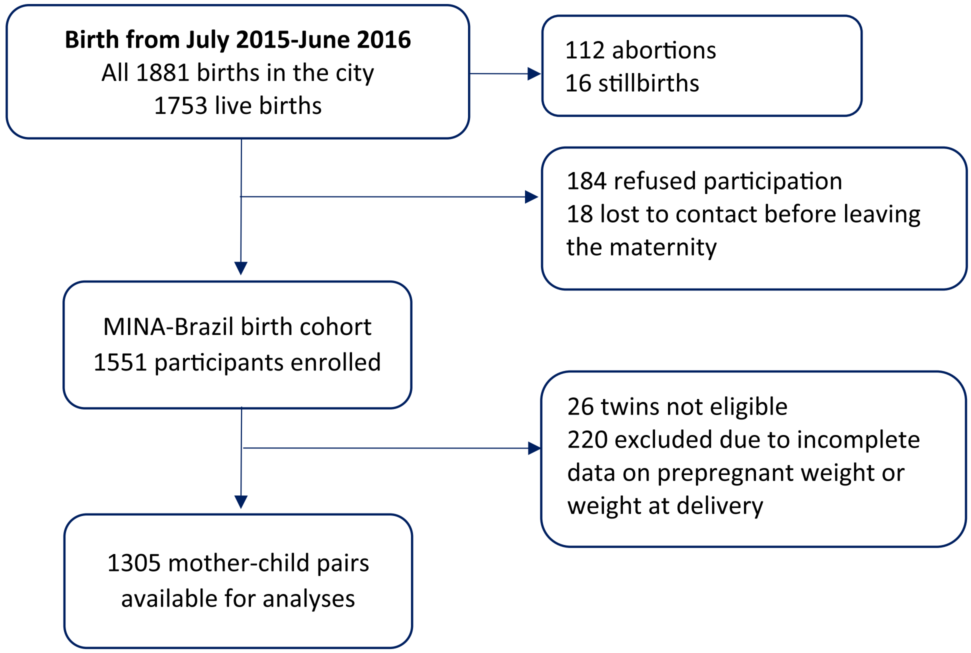

Fig. 1 Flowchart of women participants in the MINA-Brazil study

and the household wealth index, with no differences in age or skin colour.

The characteristics of women and their new-borns included in the analysis are summarised in Table 1. The mean maternal age was 24.8 (SD 6.6) years. Teenage pregnant women comprised 18.7% of the studied participants. Most women (60.8%) had 9 or more years of formal schooling and self-identified as non-white (77.6% Mulatto, 4.2% Black, 1.2% Indigenous, and 5.1% Yellow). Moreover, 60.3% were multiparae and 76.8% of women had attended at least 6 antenatal care visits in the current delivery. Half of the infants were female, and 7.0% were born prematurely.

Regarding maternal nutritional status, 58.4% were of normal weight at the beginning of the pregnancy. Excessive pre-pregnancy weight was more common (34.2%) than being underweight (7.4%). Based on the IOM guidelines, inappropriate GWG was observed in 64.7% of pregnancies, with similar rates (32%) of insufficient and excessive weight gain. Total GWG was significantly associated with maternal schooling, household wealth index, woman living with a partner, area of residence, parity, maternal height, pre-pregnancy BMI, antenatal care visits, smoking during pregnancy, hypertension during pregnancy, prior caesarean delivery, gestational iron supplementation, and GA at delivery ($P \leq 0.20$).

Pregnancy Outcomes According to IOM GWG Guidelines

Table 2 shows the associations between GWG and pregnancy outcomes. The crude analysis showed that women with excessive GWG had a higher mean BW z-score; a higher risk of macrosomia, LGA, and caesarean delivery; and a lower risk of SGA. Conversely, a lower mean BW z-score and decreased risks of LGA and caesarean delivery were observed among women with insufficient GWG (distribution of maternal and neonatal outcomes for all participants and among the IOM GWG categories are presented in Online Resource 1).

After multiple adjustments for potential confounders, excessive GWG was associated with a higher risk of macrosomia (aRR: 1.68; 95% CI 1.02, 2.76), LGA new-borns (aRR: 2.16; 95% CI 1.56, 3.01), and caesarean delivery (aRR: 1.26; 95% CI 1.11, 1.43). Conversely, excessive GWG was associated with a lower risk of LBW (aRR: 0.44; 95% CI 0.27, 0.73) and SGA (aRR: 0.38; 95% CI 0.21, 0.68) compared to that in women who gained the recommended weight. Women with insufficient and excessive GWG gave birth infants with a mean BW z-score 0.16 lower (95% CI -0.29, -0.04) and 0.41 higher (95% CI 0.29, 0.53), respectively, compared to those women in the reference group. Preterm birth, maternal Hb, and gestational anaemia were not significantly associated with GWG. Similar results were found when a sensitive analysis excluding gestation > 40 weeks was performed, except for preterm births, which were significantly more frequent among women with excessive GWG. However, this result was predictable since none of the excluded participants were preterm births (GA > 40 weeks) and many of the pregnant women had excessive GWG ($p < 0.000$) (Online Resource 2).

Table 1 Characteristics of the mother–child pairs participants by gestational weight gain according to the Institute of Medicine Guidelines, 2009. The MINA-Brazil birth cohort

Variables	All participants *n*[a] 1305	Gestational weight gain			
		Insufficient *n* 419	Adequate *n* 460	Excessive *n* 426	*P**
Maternal age, years—mean (SD)	24.8 (6.6)	24.2 (7.0)	25.2 (6.5)	24.6 (6.3)	0.342
Self-reported skin colour					
White	149 (11.9)	45 (11.2)	49 (11.1)	55 (13.4)	0.522
Non-white[b]	1107 (88.1)	356 (88.8)	394 (88.9)	357 (86.6)	
Maternal schooling, years					
≤ 9	492 (39.2)	201 (50.1)	165 (37.3)	126 (30.7)	< 0.001
> 9	763 (60.8)	200 (49.9)	278 (62.7)	285 (69.3)	
Household wealth index, tertiles					
1st lower	388 (30.9)	170 (42.4)	117 (26.4)	101 (24.5)	< 0.001
2nd	430 (34.2)	128 (31.9)	161 (36.3)	141 (34.2)	
3rd higher	438 (34.9)	103 (25.7)	165 (37.3)	170 (41.3)	
Woman living with a partner, yes	993 (79.1)	300 (74.8)	359 (81.0)	334 (81.1)	0.040
Area of residence					
Rural	204 (15.8)	93 (22.4)	59 (12.9)	52 (12.3)	< 0.001
Urban	1090 (84.2)	322 (77.6)	398 (87.1)	370 (87.7)	
Multiparae	757 (60.3)	255 (63.6)	273 (61.6)	229 (55.6)	0.051
Maternal Height, cm—mean (SD)	156.8 (6.2)	156.3 (6.3)	156.5 (6.1)	157.8 (6.1)	< 0.001
Pre-pregnancy body mass index[c]					
Underweight	96 (7.4)	34 (8.1)	41 (8.9)	21 (4.9)	< 0.001
Normal weight	762 (58.4)	301 (71.8)	261 (56.7)	200 (46.9)	
Overweight	327 (25.0)	63 (15.1)	118 (25.7)	146 (34.3)	
Obesity	120 (9.2)	21 (5.0)	40 (8.7)	59 (13.9)	
Antenatal care visits					
< 6	300 (23.2)	126 (30.4)	98 (21.4)	76 (18.1)	< 0.001
≥ 6	993 (76.8)	289 (69.6)	359 (78.4)	345 (81.9)	
Smoking during pregnancy, yes	50 (3.8)	30 (7.5)	15 (3.4)	5 (1.2)	< 0.001
Hypertension during pregnancy, yes	221 (17.1)	46 (11.1)	74 (16.2)	101 (23.9)	< 0.001
Gestational malaria, yes	99 (7.7)	37 (8.9)	33 (7.2)	29 (6.9)	0.491
Prior preterm birth, yes	85 (6.5)	32 (7.6)	26 (5.6)	27 (6.3)	0.464
Prior caesarean delivery, yes	216 (16.6)	55 (13.1)	84 (18.3)	77 (18.7)	0.073
Gestational iron supplementation, yes	867 (67.1)	284 (68.6)	315 (68.9)	268 (63.5)	0.167
Gestational age at delivery, weeks					
< 37	91 (7.0)	24 (5.7)	28 (6.1)	39 (9.2)	0.069
≥ 37–41	1180 (90.4)	385 (91.9)	424 (92.2)	371 (87.1)	
≥ 42	34 (2.6)	10 (2.4)	8 (1.7)	16 (3.7)	
New-born sex					
Female	654 (50.1)	214 (51.1)	224 (48.7)	216 (50.7)	0.747
Male	651 (49.9)	205 (48.9)	236 (51.3)	210 (49.3)	

**P* values from one-way ANOVA and chi-square test or Fisher's exact test

[a]Variation in *n* is due to missing data

[b]Among non-whites (% of total): Mullato (77.6%), Black (4.2%), Yellow (5.1%), and Indigenous (1.2%)

[c]According to the World Health Organization standards (WHO 1995)

Table 2 Crude and Adjusted maternal and neonatal outcomes by gestational weight gain according to the Institute of Medicine guidelines (2009), among participants of the MINA-Brazil birth cohort (*n* 1305)

Outcomes	Crude analysis RR[a] or β[b] (95%CI)			Adjusted analysis[c] RR[a] or β[b] (95%CI)		
	Insufficient	Adequate	Excessive	Insufficient	Adequate	Excessive
Birthweight (z-score)[d]	− 0.21 (− 0.34, − 0.86)[b]*	Reference	0.48 (0.36, 0.62)[b]*	− 0.16 (− 0.29, − 0.04)[b]*	Reference	0.41 (0.29, 0.53)[b]*
Low birthweight[e]	1.51 (0.95, 2.39)	Reference	0.55 (0.30, 1.02)	1.37 (0.93, 2.03)	Reference	0.44 (0.27, 0.73)*
Macrosomia[e]	0.57 (0.28, 1.13)	Reference	2.16 (1.33, 3.50)*	0.65 (0.34, 1.27)	Reference	1.68 (1.02, 2.76)*
Small for gestational age	1.40 (0.96, 2.04)	Reference	0.35 (0.19, 0.63)*	1.27 (0.87, 1.84)	Reference	0.38 (0.21, 0.68)*
Large for gestational age	0.58 (0.35, 0.95)*	Reference	2.43 (1.74, 3.40)*	0.63 (0.39, 1.01)	Reference	2.16 (1.56, 3.01)*
Preterm birth[f]	0.94 (0.55, 1.59)	Reference	1.50 (0.94, 2.40)	0.90 (0.54, 1.51)	Reference	1.56 (0.98, 2.49)
Caesarean delivery[g]	0.76 (0.64, 0.90)*	Reference	1.34 (1.17, 1.52)*	0.85 (0.72, 1.00)	Reference	1.26 (1.11, 1.43)*
Maternal haemoglobin (g/L)[h]	− 0.18 (− 0.36, 0.01)[b]	Reference	-0.05 (-0.24, 0.09)[b]	− 0.11 (− 0.30, 0.06)[b]	Reference	− 0.08 (− 0.27, 0.10)[b]
Gestational anaemia[h]	0.97 (0.82, 1.17)	Reference	1.05 (0.88, 1.24)	0.91 (0.79, 1.13)	Reference	1.08 (0.91, 1.28)

*$p < 0.05$

[a]Relative risk and 95% confidence interval

[b]β-Coefficient and 95% confidence interval

[c]All analyses were adjusted for maternal age, maternal schooling, household wealth index, woman living with a partner, area of residence, maternal height, pre-pregnancy body mass index, parity, smoking during pregnancy, antenatal care visits

[d]According to the Intergrowth-21st Project

[e]with further adjustment for gestational age at delivery and new-born sex

[f]with further adjustment for hypertension during pregnancy and type of delivery

[g]with further adjustment for hypertension during pregnancy, previous caesarean delivery, gestational age at delivery and macrosomia

[h]with further adjustment for gestational age at delivery and gestational iron supplementation

Comparison of the IOM and the INTERGROWTH-21st Guidelines for GWG.

Among adult women with normal pre-pregnancy BMI and GA < 40 weeks (n = 658), the prevalence of insufficient and excessive GWG according to the IOM guidelines was 41.2% (95% CI 37.3, 45.0) and 24.8% (95% CI 21.5, 28.2), respectively. In contrast, 25.2% (95% CI 21.9, 28.7) and 16.9% (95% CI 14.0, 19.9) of the participants gained a gestational weight below − 1 and above 1 z-score of the INTERGROWTH-21st standard, respectively. The distribution of maternal and neonatal outcomes among the IOM and INTERGROWTH-21st GWG categories are presented in Online Resource 3. The crude analysis indicated similar associations when comparing both methods of GWG classification. Additionally, the analysis of means and proportions did not show significant differences in outcome distribution across the corresponding GWG categories of each method.

Multiple adjusted analysis showed that women whose weight gain was excessive according to the IOM recommendations and above the INTERGROWTH-21st standards had higher risks of delivering a new-born with macrosomia (5.16- and 3.96-fold, respectively), LGA (2.90- and 3.58-fold, respectively), and higher mean BW values (0.47 and 0.48 z-scores, respectively) compared to those women whose weight gain was adequate or within − 1 to 1 z-score. Women who gained gestational weight below the INTERGROWTH-21st standards had a higher risk of delivering an SGA (1.69-fold) infant and lower mean BW value (− 0.20 z-score) compared to that in women who gained weight within the standards (Table 3).

Discussion

We found that according to the 2009 IOM guidelines, most women (64.7%) gained inappropriate gestational weight across the pre-pregnancy BMI ranges, of which approximately half experienced excessive GWG. Compared to adequate GWG, insufficient GWG was associated with a lower BW z-score. Additionally, excessive GWG was associated with higher BW z-scores, increased risks of macrosomia,

Table 3 Adjusted maternal and neonatal outcomes by gestational weight gain according to the Institute of Medicine guidelines (2009) and Intergrowth-21st standard, among adult women with normal pre-pregnancy body mass index and gestational age less than or equal to 40 weeks (*n* 658). The MINA-Brazil birth cohort

	IOM recommendations RR[a] or β[b] (95%CI)[c]			Intergrowth-21st (z-score) RR[a] or β[b] (95%CI)[c]		
Outcomes	Insufficient *n* 271	Adequate *n* 224	Excessive *n* 163	below (< − 1) *n* 166	within (± 1) *n* 381	Above (> 1) *n* 111
Birthweight (z-score)[d]	− 0.12 (− 0.28, 0.04)[b]	Reference	0.47 (0.29, 0.65)[b]*	− 0.20 (− 0.36, − 0.03)[b]*	Reference	0.48 (0.29, 0.67)[b]*
Low birthweight[e]	0.95 (0.55, 1.63)	Reference	0.47 (0.22, 1.00)	1.38 (0.81, 2.34)	Reference	0.65 (0.25, 1.69)
Macrosomia[e]	1.16 (0.28, 4.74)	Reference	5.16 (1.57, 16.93)*	1.29 (0.39, 4.23)	Reference	3.96 (1.63, 9.61)*
Small for gestational age	1.28 (0.76, 2.15)	Reference	0.53 (0.24, 1.17)	1.69 (1.04, 2.75)*	Reference	0.64 (0.27, 1.52)
Large for gestational age	0.68 (0.32, 1.47)	Reference	2.90 (1.58, 5.13)*	0.71 (0.31, 1.60)	Reference	3.58 (2.19, 5.86)*
Preterm birth[f]	0.63 (0.33, 1.18)	Reference	1.25 (0.66, 2.38)	0.90 (0.47, 1.73)	Reference	1.42 (0.72, 2.97)
Caesarean delivery[g]	0.84 (0.68, 1.04)	Reference	1.18 (0.96, 1.45)	0.78 (0.61, 1.00)	Reference	1.20 (0.97, 1.47)
Maternal haemoglobin (g/L)[h]	− 0.17 (− 0.44, 0.08)[b]	Reference	− 0.26 (− 0.56, 0.04)[b]	− 0.14 (− 0.41, 0.13)[b]	Reference	− 0.20 (− 0.51, 0.11)[b]
Gestational anaemia[h]	0.95 (0.75, 1.20)	Reference	1.15 (0.90, 1.47)	0.97 (0.76, 1.23)	Reference	1.16 (0.90, 1.49)

IOM Institute of Medicine

*$p < 0.05$

[a]Relative risk and 95% confidence interval

[b]β-Coefficient and 95% confidence interval

[c]All analyses were adjusted for maternal age, maternal schooling, household wealth index, woman living with a partner, area of residence, maternal height, pre-pregnancy body mass index, parity, smoking during pregnancy, antenatal care visits

[d]According to the Intergrowth 21st Project

[e]with further adjustment for gestational age at delivery and new-born sex; analysis following Intergrowth-21st standards was not adjusted for gestational age at delivery

[f]with further adjustment for hypertension during pregnancy and type of delivery

[g]with further adjustment for hypertension during pregnancy, previous caesarean delivery, gestational age at delivery and macrosomia; analysis following Intergrowth-21st standards was not adjusted for gestational age at delivery

[h]with further adjustment for gestational age at delivery and gestational iron supplementation; analysis following Intergrowth-21st standard was not adjusted for gestational age at delivery

LGA new-borns, and caesarean delivery; and lower risks of LBW and SGA neonates, regardless of socioeconomic or obstetric characteristics. Among women with normal pre-pregnancy BMI, the prevalence of inappropriate GWG was high, irrespective of the method used to evaluate weight gain. GWG above recommendations of IOM or INTERGROWTH-21st was associated with an increased risk of macrosomia and LGA, whereas GWG below the INTERGROWTH-21st was associated with an increased risk of SGA.

The substantial percentage of women with inappropriate GWG found in this study is consistent with the findings of several studies, based on the IOM recommendations, which showed that most women end their gestation without having an optimal weight, regardless of whether they live in a high-(Goldstein et al., 2017) or low-middle income country (Jin et al., 2019; Ouédraogo et al., 2020). Nevertheless, in this study, similar rates of insufficient (32.1%), adequate (35.3%), and excessive (32.6%) GWG were observed. In this regard, although previous studies have also shown that around 30% of pregnant women gained adequate GWG according to the IOM recommendations, a predominance of either insufficient (Young et al., 2018) or excessive GWG (Goldstein et al., 2017; Jin et al., 2019) has been described. Thus, our results indicate that the studied population faces unfavourable pregnancy outcomes derived from both extremes of GWG. Preconception counselling to promote healthy diet and physical activity behaviours among pregnant women, integrated with broad policies and local programs to diminish disparities in access to healthy food are fundamental to promote appropriate GWG.

As previously disclosed (Mohamed et al., 2022), pre-pregnancy BMI itself is a predictor of child BW; likewise, GWG has an impact on offspring BW independent of pre-pregnancy BMI. Thus, with an increase in either pre-pregnancy BMI or GWG, a high BW could be expected. Hence, our findings regarding lower BW z-scores among pregnant women with insufficient GWG and higher BW z-scores among pregnant women with excessive GWG, when compared with those women with adequate GWG, seem accurate. However, in our cohort, insufficient GWG was not associated with other BW outcomes, such as LBW and SGA, indicating that the BW measurement remained within an acceptable weight range in this GWG group. This finding is in line with another cohort study with migrant women living in the USA, mainly from Mexico and Ecuador, which indicated that a GWG lower than recommended, if closely monitored, may not be a real disadvantage (Deierlein et al., 2020). Conversely, a recent meta-analysis from regions around the world, mainly from developed countries, reaffirmed the association between GWG below IOM recommendations and adverse pregnancy outcomes (Goldstein et al., 2017). While these inconsistent results can be due to methodological differences, further research into the benefits of using the lower limit of the GWG gain ranges recommended by the IOM in different settings, is needed.

Similar to our findings, the associations between excessive GWG and the increased risk of macrosomia (Goldstein et al., 2017), LGA infants, and caesarean delivery (Rogozińska et al., 2019) have been previously reported. The increased risk of these outcomes associated with excessive GWG is beyond the risk associated with pre-pregnancy BMI, which also has an effect on size at birth (Mohamed et al., 2022) and caesarean delivery (Xiong et al., 2016). Previous studies showed that excessive GWG promotes greater new-born body fat (Nehab et al., 2020), obesity in childhood (Widen et al., 2016), and greater BMI in early adulthood (Mamun et al., 2009). Recent evidence has shown that the GWG influences child BMI across three generations (Schneider et al., 2021). Similarly, dyslipidaemia among pregnant women with excessive weight may impact myometrial contractility impeding vaginal delivery and increasing the rates of caesarean delivery (Chin et al., 2012), which was also associated with overweight and obese offspring (Li et al., 2013); thus perpetuating the cycle of obesity.

Few studies have described GWG comparing both methods (Adu-Afarwuah et al., 2017; Jin et al., 2019; Ouédraogo et al., 2020), and all studies, regardless of the cut-off point used for INTERGROWTH-21st graphs (± 2 or ± 1 z-score), have also found higher estimates of inappropriate GWG by the IOM. These findings reflect the narrower adequate total GWG range recommended by the IOM when compared to the INTERGROWTH-21st standards. We set a cut-off point of ± 1 z-score, which is equivalent to the 16th and 84th percentiles, out of which the risks of perinatal outcomes are expected to increase as they approach the extreme values of weight gain in the reference charts. In addition, a recent study conducted in China that evaluated the ability of the INTERGROWTH-21st standards to identify women at risk of gestational diabetes (GDM) compared with local and IOM recommendations found that the risk ratio of the development of GDM started to increase after z-scores exceeded 1 (Jin et al., 2019). Considering that the use of patterns of GWG along with the specific interpretation of z-scores have the additional advantage of alerting clinicians against deviations in weight (Cheikh Ismail et al., 2016), the INTERGROWTH-21st charts for GWG may be an alternative to address the knowledge gap in optimal GWG, especially in countries without specific recommendations.

This study has several strengths. We described GWG and pregnancy-related outcomes using data from a population-based birth cohort study in the Western Brazilian Amazon. The detailed information on the relevant variables was collected by trained research personnel, thus reducing the risk of information bias. Furthermore, to avoid classification error (Gilmore & Redman, 2015), the GWG for preterm deliveries was estimated by taking into consideration the length of gestation before assessing adherence to the IOM GWG guidelines. However, some limitations should be noted. First, the pre-gestational weight of some mothers was self-reported, possibly resulting in a recall bias. However, in this cohort, the self-reported pre-pregnancy weight registered in the prenatal card was in good agreement with the standardised research measurements. Second, the different baseline characteristics of women included in the analyses and those women living in rural areas who were excluded because of missing data could have caused selection bias. Thus, our results may be generalizable only for mothers living in urban area. Finally, the comparative description of GWG between IOM guidelines and INTERGROWTH-21st standards included only women with normal pre-pregnancy BMIs. Therefore, these results cannot be generalised for women who start pregnancy in a different BMI category.

Conclusion

Insufficient GWG was associated with lower BW z-scores while excessive GWG was associated with an increased risk of caesarean delivery and an increase in size at birth. Among women with normal pre-pregnancy BMI, GWG above the IOM recommendations or

INTERGROWTH-21st standards was associated with similar risks of BW outcomes. However, BW adverse outcomes were observed only among women who gained gestational weight below the INTERGROWTH-21st standards, suggesting that this method can better guide ideal weight gain during pregnancy among healthy women in our population.

Appendix

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Declarations

Conflict of interest None to declare.

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