BMC Pregnancy and Childbirth

RESEARCH

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Predictors of inadequate gestational weight gain according to iom recommendations and intergrowth-21st standards: the araraquara cohort study

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Abstract

Background Gestational weight gain (GWG) is a critical factor for maternal and fetal health.

Objective To identify maternal predictors of inadequate GWG according to the 2009 Institute of Medicine (IOM) recommendations and Intergrowth-21st standards.

Methods A prospective epidemiological cohort study conducted from 2017 to 2023 in southeastern Brazil assessed 1,557 women at three different stages of pregnancy (≤ 18, 20–26, and 30–36 weeks of gestation) and at delivery. Sociodemographic, obstetric, lifestyle, nutritional, and maternal morbidity characteristics were collected, along with biochemical parameters.

Results Among the participants, 38.7% had GWG above IOM recommendations, while 67.5% had GWG above the Intergrowth-21st standards. Multinomial logistic regression analysis showed that women with pre-pregnancy obesity and women with the highest body fat percentage had, respectively, a 95% (OR = 1.95; 95% CI: 1.08–3.51) and 1% (OR = 1.01; 95% CI: 1.01–1.05) higher chance of GWG above IOM recommendations. Pregnant women in the lowest tertile of height, smokers, number of previous pregnancies, and women living in crowded homes had, respectively, a 57% (OR = 0.57; 95% CI: 0.41–0.80), 36% (OR = 0.64; 95% CI: 0.37–0.86), 35% (OR = 0.65; 95% CI: 0.43–0.97), and 14% (OR = 0.86; 95% CI: 0.59–0.86) lower chance of GWG above IOM recommendations. Women with diabetes were 2.53 times more likely (OR = 2.53; 95% CI: 1.32–4.83) to have GWG below IOM recommendations. Using the Intergrowth-21st standards, women with the highest body fat percentage had a 12% (OR = 1.12; 95% CI: 1.02–1.24) higher chance of GWG above the 90th percentile. Pregnant women in the lowest tertile of height were 2.82 times more likely (OR = 2.82; 95% CI: 1.08–8.13) and women with the lowest hemoglobin concentrations had a 41% lower chance (OR = 0.59; 95% CI: 0.39–0.88) of having GWG below the 10th percentile. While both guidelines identified body fat percentage and pre-pregnancy obesity as significant predictors of excessive GWG, the Intergrowth-21st standards captured a higher percentage of women exceeding GWG limits.

Conclusion The findings underscore the importance of comparing two instruments for assessing the adequacy of GWG. The IOM and Intergrowth-21st standards provide complementary insights, which can help implement

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targeted interventions for specific groups of women based on their nutritional and socioeconomic status, lifestyle, and obstetric factors to prevent pregnancy-related complications.

Keywords Gestational weight gain, Predictors, Cohort study, IOM recommendations, Intergrowth-21st standards

Introduction

Pregnancy is a period characterized by significant changes that have direct implications for fetal health. Gestational weight gain (GWG) is essential to ensure the well-being of both the mother and the fetus; however, it still poses a challenge for many pregnant women because of the physical and psychological alterations that occur during this period of life [1]. Additionally, in countries with persistent social inequalities like Brazil, socioeconomic disparities, for example in income and maternal education level, can affect GWG [2–4]. Women with lower income levels are more likely to experience inadequate GWG, either insufficient or excessive, which can lead to adverse maternal and neonatal outcomes [5, 6].

In recent decades, obesity has become more prevalent worldwide and also affects women of reproductive age [1]. It is estimated that over 21% of women worldwide will be obese by 2025 [7]. Obesity can significantly impact GWG, as obese women are more likely to experience excessive GWG, which poses further health risks for both the mother and the baby [8, 9]. Since they are a serious public health threat in low, middle- and high-income countries, obesity and overweight have become a growing concern for health authorities [10].

Inadequate GWG is associated with a range of complications for both the mother and the baby, including gestational diabetes, hypertension, and preeclampsia [11–13]. Demographic, socioeconomic, biological, dietary, psychological, behavioral, and health-related factors can influence GWG [14–16]. For instance, lower socioeconomic status is often associated with inadequate GWG, either insufficient or excessive, due to limited access to nutritious food and prenatal care. Higher levels of psychological stress and certain dietary patterns can also lead to excessive GWG. Therefore, understanding these factors can help identify women at risk and implement necessary intervention strategies and public policies designed to promote adequate GWG and to improve maternal and child health [17].

There are few large cohort studies in Brazil that have investigated the prevalence of and factors associated with GWG [16, 18, 19]. In Pelotas, Rio Grande do Sul state, the prevalence of adequate GWG was 30.9%, while 47% of women had pre-pregnancy overweight or obesity. There was a rapid increase in GWG above the recommended level over a period of 30 years, particularly among lower-income women [18, 19]. In Rio de Janeiro, Rio de Janeiro state, 44% of pregnant women had insufficient GWG and 22% had excessive GWG. Risk factors for insufficient GWG included pre-pregnancy underweight, maternal age above 25 years, early menarche, and a history of smoking, while risk factors for excessive GWG included pre-pregnancy overweight, lower socioeconomic status, and high caloric intake [16].

The recommendations of the Institute of Medicine (IOM) have been used to classify GWG since the 1990s; however, they have limitations since they were based on cross-sectional studies of pregnant women exclusively from a single country, the United States [20, 21]. It was only in 2016 that new international reference curves, the Intergrowth-21.st standards, were developed using a multiethnic cohort of healthy, well-nourished, and educated mothers from eight countries, including Brazil. These new standards provided a prescriptive reference chart for GWG [22]. In 2022, there was also the publication of a Brazilian curve, currently adopted by the Brazilian Ministry of Health [23, 24].

There are still gaps in knowledge regarding predictors of GWG in low- and middle-income countries, particularly when a more representative curve such as Intergrowth-21st is used. Additionally, given the vast territory and existing socioeconomic, cultural, and dietary disparities in Brazil, conducting studies in different regions is crucial to better understand this issue. Therefore, the aim of this original study was to identify maternal predictors of GWG according to the 2009 IOM recommendations and Intergrowth-21st standards in Brazilian pregnant women enrolled in a large prospective cohort study.

Materials and methods

Study design and participants

This prospective population-based cohort study conducted from 2017 to 2023 was embedded in an ongoing larger study, called the "Araraquara Cohort Study". The sample included 1,557 women with gestational age ≤ 18 weeks who underwent prenatal care at the 34 Health Units in the city of Araraquara, São Paulo state, southeastern Brazil.

The pregnant women were selected by trained interviewers The participants answered a questionnaire previously tested in pregnant women, which consisted of demographic and socioeconomic characteristics (age, race, marital status, and educational level), lifestyle

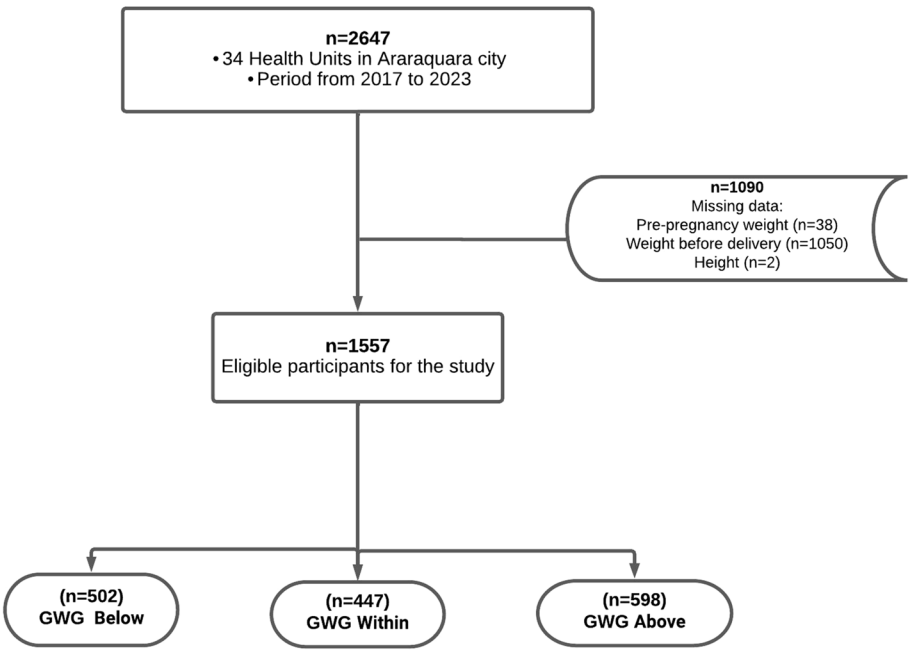

Fig. 1 Selection of the study population according to IOM recommendations

(smoking and alcohol consumption), obstetric (gestational age and parity), and morbidity characteristics. The women attended the municipal maternity of Araraquara for ultrasound measurements before 18 weeks of gestation to confirm their gestational age.

The pregnant women participating in the study were followed up at three different stages of pregnancy (≤18, 20–26, and 30–36 weeks of gestation) until the birth of their children. Women with twin pregnancies, miscarriages, fetal death, and stillbirths were excluded. Pregnant women with missing information on height, pre-pregnancy weight, and weight at the time of delivery were also excluded (Fig. 1). To permit adjustment to the Intergrowth-21st standards, only pregnant women with a pre-pregnancy body mass index (BMI) within the normal range (18.5–24.9 kg/m^2) and without morbidity were included in the study (Table 1 and Fig. 2).

Outcome variables

GWG was calculated as the difference between weight at delivery and pre-pregnancy weight. Next, GWG was classified into three categories according to the recommendations of the IOM: (a) GWG below IOM recommendations; (b) GWG within IOM recommendations, and (c) GWG above IOM recommendations [20] (Table 2). For the classification of GWG based on Intergrowth-21st, the gestational age-specific GWG percentile of the international GWG standards for women with normal BMI was used, which defines a GWG between the 10th and 90th percentile as appropriate. Thus, pregnant women below the 10th percentile and above the 90th percentile of the Intergrowth-21st standards were classified as having insufficient and excessive GWG, respectively [22, 25, 26] (Table 1).

Table 1 Intergrowth-21st standards for GWG

GWG Percentile	Classification	GWG (kg)
Below 10th	Insufficient	12.5–18
10th—90th	Adequate	11.5–16
Above 90th	Excessive	7–11.5

Maternal predictors

Several factors were considered for the prediction of GWG. Socioeconomic and demographic factors included age (≤19, 20–35, or >35 years), educational level (<4, 5–11, or ≥12 years of schooling), per capita income in Brazilian Real (1 US$ = 4.9 R$), race (white or non-white), marital status (married/stable union or single/separated/widowed), and number of previous pregnancies (0, 1, or ≥2). Lifestyle factors included physical activity, smoking, and alcohol consumption. Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ), which is widely used in studies in Brazil, and was categorized as "yes" or "no" based on whether participants met the recommended levels of physical activity [27], Alcohol consumption was assessed

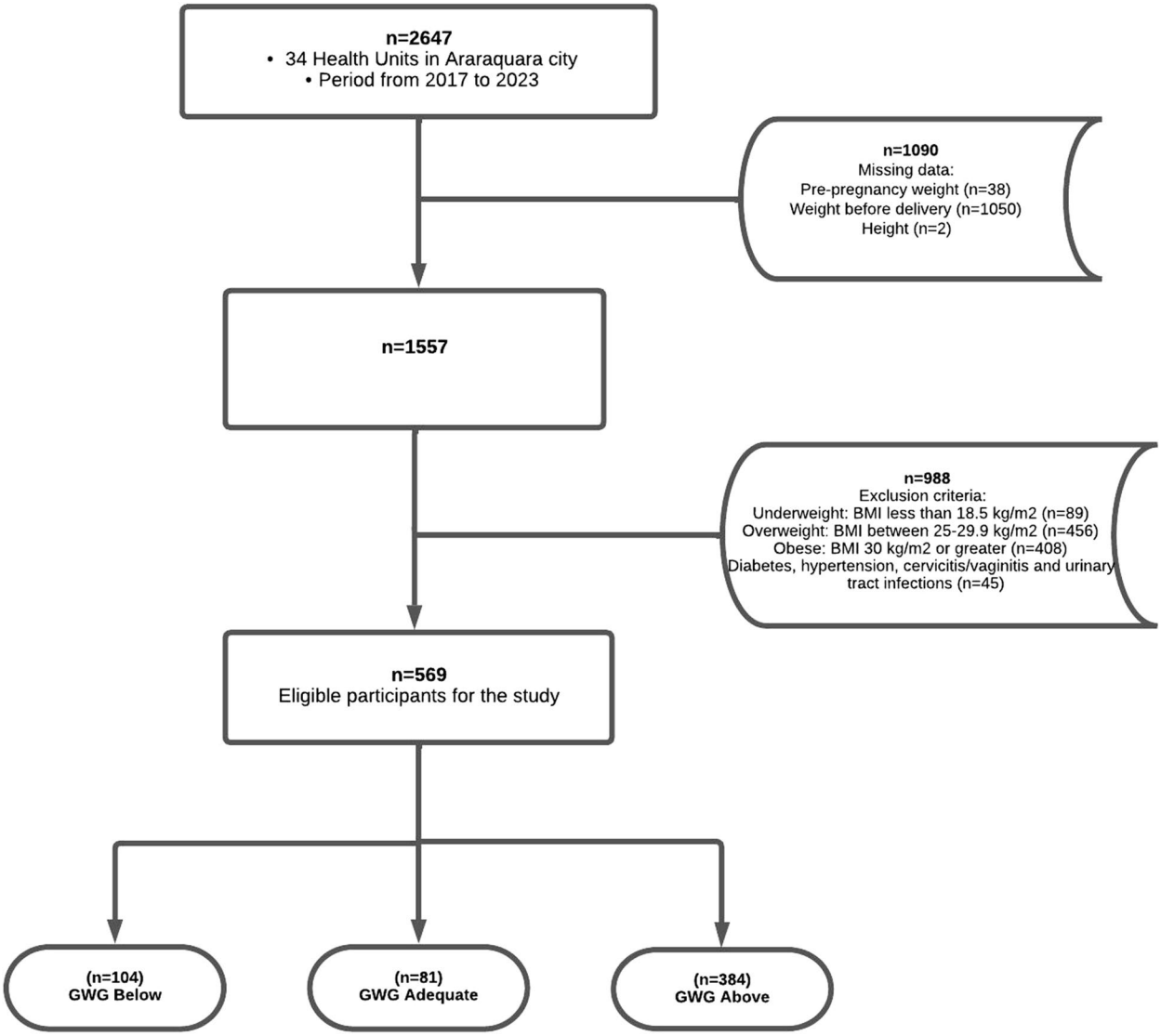

Fig. 2 Selection of the study population according to Intergrowth-21st standards

Table 2 IOM recommendations for GWG [20]

Nutritional status	Pre-pregnancy BMI (kg/m^2)	GWG (kg)
Underweight	< 18.5	**12.5–18**
Normal weight	18.5–24.9	**11.5–16**
Overweight	25–29.9	**7–11.5**
Obesity	≥ 30.0	5–9

BMI body mass index, *GWG* gestational weight gain

by both frequency and quantity, and was categorized into "no consumption", "occasional consumption" (up to once a week), and "regular consumption" (more than once a week). Morbidity included diabetes, hypertension, urinary tract infection, and cervicitis/vaginitis.

Anthropometry of the pregnant women was assessed based on height (cm) categorized into tertiles; BMI categories were defined according to the World Health Organization (WHO) classification as follows: underweight (< 18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obesity (≥ 30.0 kg/m^2); arm circumference (cm) categorized as low weight (< 23 cm), adequate (25–28 cm), and overweight or obesity (≥ 28 cm), and body fat percentage. Other relevant data included gestational age at birth, glycemic profile (fasting blood glucose [mg/dL], insulin [μIU/mL], HOMA [μIU/mL], glycated hemoglobin [%]),

high-sensitivity C-reactive protein (hs-CRP [ng/mL]), hemoglobin [g/dL], and lipid profile (total cholesterol, LDL-c, HDL-c, and triglycerides [mg/dL]). Additionally, the number of household members per room was categorized into tertiles, with the highest tertile defined as "crowded," and the number of previous pregnancies was categorized as 0, 1, and ≥ 2.

Statistical analysis

Descriptive statistics was used for description of the sample. The Shapiro–Wilk test was applied to assess the normality of continuous variables. Continuous variables with a non-normal distribution were reported as median and interquartile range, while categorical variables were expressed as number (n) and percentage (%).

Bivariate analysis was performed to examine the associations between the independent variables and the dependent variable. The Kruskal–Wallis test was used for continuous variables, while the chi-square test or Fisher's exact test was applied to categorical variables. Data modeling was performed by multinomial logistic regression, which allows the analysis of associations between multiple independent variables and a dependent variable with three or more ordered categories, as is the case of the GWG adequacy categories according to IOM recommendations or Intergrowth-21st standards [25, 28]. The models were adjusted using a stepwise strategy, which is an iterative method that selects and removes independent variables based on statistical criteria. Variables with $p < 0.2$ were maintained in the model. For the adjustment process, variables predicted in the initial theoretical model were considered along with other potentially relevant variables identified in a literature review. The results were expressed as the following measures of association: odds ratio (OR) and 95% confidence interval (CI). All analyses were performed using R version 4.1.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 1,557 pregnant women were included in this study. Of these, 447 (28.7%), 506 (32.5%) and 604 (38.7%) had weight gain within, below and above the 2009 IOM recommendations, respectively. On the other hand, among 569 pregnant women with normal pre-pregnancy BMI, 81 (14.2%), 104 (18.3%) and 384 (67.5%) had weight gain within, below and above the Intergrowth-21st standards (Tables 3 and 4).

Maternal characteristics associated with GWG according to IOM recommendations

Maternal height was significantly associated with GWG ($p = 0.003$), with the highest weight gain being observed in the upper tertile (> 66.6%) of height. Pre-pregnancy BMI was also significantly associated with GWG ($p < 0.001$), with overweight and obese pregnant women showing GWG. Similarly, arm circumference, body fat percentage, maternal education, number of individuals per room, and per capita income were all significantly associated with GWG ($p < 0.001$) (Table 3).

Regarding lifestyle factors, smoking was significantly associated with GWG ($p < 0.001$), while physical activity or alcohol consumption showed no significant association ($p = 0.951$ and $p = 0.885$, respectively). Pregnant women with diabetes had lower GWG compared to those without diabetes ($p < 0.001$). However, no significant differences were observed for hypertension, urinary tract infection, cervicitis/vaginitis, or number of previous pregnancies. Finally, hemoglobin and HDL-c were significantly associated with GWG ($p = 0.002$ and $p = 0.012$, respectively), but no significant associations were found for hs-CRP, HOMA, glycated hemoglobin, fasting insulin, total cholesterol, LDL-c, or triglycerides.

Maternal characteristics associated with GWG according to Intergrowth-21st standards

Maternal age was not significantly associated with GWG ($p = 0.292$). Similarly, no significant association with GWG was found for pre-pregnancy BMI, per capita income, race, marital status, physical activity, smoking, alcohol consumption, number of previous pregnancies, hs-CRP, HOMA, LDL-c, HDL-c, or total cholesterol levels (Table 5).

On the other hand, maternal height was found to be significantly associated with GWG ($p = 0.034$), with the highest weight gain being observed in the lowest tertile (< 33.3%) of height. The highest arm circumference ($p = 0.007$) and body fat percentage ($p < 0.001$) were also significantly associated with GWG.

Predictors of GWG according to IOM recommendations

Adjusted multinomial logistic regression analysis showed that women with a pre-pregnancy BMI indicating obesity and women with the highest body fat percentage had, respectively, a 95% (OR = 1.95; 95% CI: 1.08–3.51) and 1% (OR = 1.01; 95% CI: 1.01–1.05) higher chance of GWG above IOM recommendations (Table 4). Pregnant women in the lowest tertile of height, smokers, women with ≥ 2 previous pregnancies, and women living in crowded homes had, respectively, a 43% (OR = 0.57; 95% CI: 0.41–0.80), 36% (OR = 0.64; 95% CI: 0.37–0.86), 35% (OR = 0.65; 95% CI: 0.43–0.97), and 14% (OR = 0.86; 95% CI: 0.59–1.26) lower chance of

Table 3 Maternal characteristics associated with gestational weight gain, in relation to IOM recommendations

Variables		Gestational Weight Gain (IOM-2019)			*P*value
		Within	Below	Above	
	Overall	447(28.7)	506(32.5)	604(38.7)	
Age (years)					
≤ 19	154(9.9)	47(3.02)	51(3.28)	56(3.6)	0.531
20–35	1189(76.4)	346(22.22)	389(25)	454(29.16)	
> 35	214(13.7)	54(3.47)	66(4.24)	94(6.04)	
Height(cm)					
1º tertile	534(34.34)	167(10.73)	187(12.03)	180(11.57)	0.003
2º tertile	505(32.48)	146(9.39)	170(10.93)	189(12.15)	
3º tertile	516(33.18)	134(8.62)	147(9.45)	235(15.11)	
Pre-gestational BMI (kg /m^2)	25.6(22.2–30.2)	25(21.3–28.6)	24.8(21.8–30.2)	26.8(23.2–31.2)	< 0.001
Pre-gestational BMI					
Underweight	89(5.7)	29(1.86)	38(2.44)	22(1.41)	< 0.001
Normal weight	604(38.8)	194(12.46)	226(14.52)	184(11.82)	
Overweight	456(29.3)	139(8.93)	109(7)	208(13.36)	
Obesity	408(26.2)	85(5.46)	133(8.54)	190(12.2)	
Arm circumference(cm)					
< 23	67(4.37)	23(1.50)	29(1.90	15(0.89)	< 0.001
23–28	474(31)	147(9.61)	190(12.42)	137(8.95)	
> 28	989(64.64	264(17.25)	283(18.50)	442(28.89)	
Body fat (%)	33.3(28.3–37.8)	32.3(26.9–36.6)	32.3(26.6–37)	34.7(30.3–39.1)	< 0.001
Gestational age (weeks)	39.4(38.5–40.3)	39.4(38.7–40.3)	39.2(38.1–40.1)	39.7(38.9–40.4)	
Maternal education (years)					
≤ 4	10(0.6)	1(0.06)	5(0.32)	4(0.26)	< 0.001
5–11	1181(75.9)	342(21.97)	389(24.98)	450(28.9)	
≥ 12	365(23.5)	104(6.68)	111(7.13)	150(9.63)	
Number of people per room					
1º tertile	533(34.25)	143(9.19)	150(9.64)	240(15.42)	0.004
2º tertile	511(32.84)	153(9.83)	169(10.86)	189(12.15)	
3º tertile	512(33.90)	151(9.70)	187(12.02)	174(11.18)	
Per capita income (R$)	666.7(400–1000)	665.9(400–970)	600(382.4–1000)	668(466.6–1000)	0.002
Race					
White	722(46.3)	208(13.36)	223(14.32)	291(18.69)	0.392
Non-white	835(53.6)	239(15.35)	283(18.18)	313(20.1)	
Marital status					
Married or in a stable relationship	1359(87.3)	388(24.93)	441(28.32)	530(34.04)	0.896
Single, separated, or widowed	198(12.7)	59(3.79)	65(4.17)	74(4.75)	
Physical activity					
Adequate	175(11.2)	50(3.21)	59(3.794)	66(4.24)	0.951
Inadequate	524(33.7)	156(10.02)	172(11.05)	196(12.59)	
Smoking					
No	1434(92.1)	409(26.27)	449(28.84)	576(36.99)	< 0.001
Yes	123(7.9)	38(2.44)	57(3.66)	28(1.8)	
Alcohol consumption					
No	1238(79.5)	353(22.67)	401(25.75)	482(30.96)	0.885
Yes	319(20.5)	94(6.04)	105(6.74)	120(7.71)	
Diabetes					
No	1479(95,0)	429(27.55)	459(29.48)	591(37.96)	< 0.001
Yes	78(5)	18(1.16)	47(3.02)	13(0.83)	

Table 3 (continued)

Variables		Gestational Weight Gain (IOM-2019)			*P*value
		Within	Below	Above	
	Overall	447(28.7)	506(32.5)	604(38.7)	
Hypertension					
No	1448(93)	420(26.97)	470(30.19)	558(35.84)	0.608
Yes	109(7)	27(1.73)	36(2.31)	46(2.95)	
Urinary Tract Infection					
No	1378(88.5)	400(25.69)	448(28.77)	530(34.04)	0.682
Yes	179(11.5)	47(3.02)	58(3.73)	74(4.75)	
Cervicitis/Vaginitis					
No	1449(93.1)	410(26.33)	472(30.31)	567(36.42)	0.3873
Yes	108(7)	37(2.38)	34(2.18)	37(2.38)	
Number of previous pregnancies					
0	620(39.8)	169(10.85)	180(11.56)	271(17.41)	0.025
1	439(28.2)	136(8.73)	145(9.31)	158(10.15)	
≥ 2	498(32)	142(9.12)	181(11.62)	175(11.24)	
hs-CRP (ng/mL)	5.9(3.1–11.7)	5.1(3–10)	6.1(3.2–11.9)	6.5(3.0–12.6)	0.137
HOMA (uUI/mL)	1.36(0.9–2.1)	1.4(0.9–2.1)	1.3(0.99–2.1)	1.42(1–2.2)	0.094
Hemoglobin (g/dL)	12.5(12–13.1)	12.6(11.9–13.1)	12.4(11.8–13)	12.6(121–13.2)	0.002
Glycated hemoglobin %,	5.1(4.9–5.3)	5.1(4.9–5.3)	5.1(4.9–5.3)	5(4.8–5.3)	0.059
Fasting insulin (uUI/mL)	7(5–11)	7(5–11)	7(5–10)	7(5–11)	0.066
Cholesterol (mg/dL)	173(151–196)	172(152–196)	172(149–194)	174(152–198)	0.526
HDL-c (mg/dL)	56(48 -64)	56(49–64)	55(47 -62)	56(49 -65)	0.012
LDL-c(mg/dL)	95(77 -113)	94(79 -111)	94(76 -112)	96(77 -115)	0.639
Triglycerides (mg/dL)	104(81–133)	104(80–134)	106(85–137)	100(80–129)	0.13

Data are presented as number (percentage) and median and interquartile range (percentile 25—percentile 75)

Statistical differences among gestational weight gain groups were tested with: Kruskal–Wallis test for continuous variables and χ2 test, Fisher's test for categorical variables

1 Brazilian Real (R$) ₌ 4.9 US$

Abbreviations: *BMI* body mass index, *LDL-c* low density lipoprotein cholesterol, *HDL-c* high-density lipoprotein cholesterol. 1º tertile: < 33.3%, 2º tertile: ≥ 33.3%; ≤ 66.6% and 3º tertile: ≥ 66.6%

GWG above IOM recommendations compared to those not in these categories (Table 4).

Predictors of GWG according to Intergrowth-21st standards

Women with the highest body fat percentage had a 12% (OR = 1.12; 95% CI: 1.02–1.24) higher chance of GWG above the 90th percentile. Pregnant women in the lowest tertile of height were 2.82 times more likely (OR = 2.82; 95% CI: 1.08–8.13) to have GWG below the 10th percentile. Additionally, women with the lowest hemoglobin concentrations had a 41% lower chance (OR = 0.59; 95% CI: 0.39–0.88) of GWG below the 10th percentile, as also shown in Table 6.

Discussion

The results of this study highlight the importance of analyzing the predictors of GWG using different reference standards, such as the IOM recommendations and the Intergrowth-21st standards. It was observed that, when using the Intergrowth-21st standards, a higher proportion of women were classified as having GWG above the 90th percentile compared to the IOM recommendations. This underscores the relevance of considering multiple instruments when assessing GWG adequacy, as different references can result in different classifications.

These findings corroborate those reported by Jin et al. (19) who compared the IOM recommendations, Intergrowth-21st standards and a local reference curve for

Table 4 Maternal characteristics associated with gestational weight gain, according to Intergrowth-21st Standards

Variables		Gestational Weight Gain-Intergrowth-21st Standards			*P*value
	Overall	Within	Below	Above	
		81(14.2)	104 (18.3)	384 (67.5)	
Age (years)					
≤ 19	86(15.1)	11(1.9)	23 (4.0)	52(9.1)	0.292
20–35	422(74.2)	61(10.7)	70(12.3)	291 1.4)	
> 35	61(10.7)	9(3.9)	11(3.5)	41(3.3)	
Height(cm)					
1º tertile	192(33.8)	19(3.3)	42(7.4)	131 (23.0)	0.034
2º tertile	197(34.7)	29 (5.1)	40(7.0)	128(22.5)	
3º tertile	179(31.5)	33(5.8)	22(3.9)	124(21.8)	
Pre-gestational BMI (kg /m^2)	22.1(20.5–23.5)	22.2(20.7–23.5)	22.3(20.3–23.7)	22.0(20.3–23.4)	0.08
Arm circumference (cm)	26.5(20–28)	26.5(25–28)	26(24.5–27.5)	27.2(25.7–28.5)	0.007
Body fat (%)	28.4(25.3–31.3)	29(26.4–32.2)	27.70(25.5–30.3)	28.4(25.2–31.1)	< 0.001
Gestational age (weeks)	39.6(38.6–40.3)	39.7(38.5–40.6)	39.0(38.1–38.5)	39.7(38.5–40.3)	< 0.001
Maternal education (years)					
< 12	478 (74.8)	67(11.8)	88(15.5)	323(56.8)	0.935
≥ 12	91(25.6)	14(2.5)	16(2.8)	61(10.7)	
Number of people per room					
1º tertile	217(38.2)	35(6.1)	40(7.04)	142(25)	0.649
2º tertile	171(30.1)	24(4.2)	27(4.8)	120(25.1)	
3º tertile	180(31.7)	22(3.9)	37(6.5)	121(21.3)	
Per capita income (R$)	666.7(425.3–1000)	687.5(447.5–1200)	625(400–1000)	700(433.3–1000)	0.125
Race					
White	245(43.1)	34 (5.9)	176 (8.3)	161(28.8)	0.42
Non-white	324(56.9)	47(8.2)	25(10.0)	20(36.7)	
Marital status					
Married or in a stable relationship	503(88.4)	73(12.8)	90(15.8)	340(59.6)	0.743
Single, separated, or widowed	66(11.6)	8(1.4)	14(2.5)	44(7.7)	
Physical activity					
Adequate	59(23.9)	5(2.0)	8(3.3)	46(18.7)	0.413
Inadequate	187(76.0)	23(9.3)	35(14.2)	129(52.4)	
Smoking					
No	529(92.9)	77(13.5)	97(17.0)	355(62.4)	0.698
Yes	40 (7.0)	4(0.7)	7(1.2)	29(5.1)	
Alcohol consumption					
No	456(80.2)	69(12.1)	83(146)	304(53.4)	0.465
Yes	113(19.8)	12(2.1)	21(3.7)	80(14.1)	
Number of previous pregnancies					
0	272(47.8)	47(8.3)	43(7.6)	182(32.0)	0.071
1	159(27.9)	13(2.3)	36(6.3)	110(19.3)	
≥ 2	138 (24.3)	21(3.7)	25(4.4)	92(16.2)	
hs-CRP (ng/mL)	4.2(2.3- 7.2)	3.8(2.3- 8.2)	4.5(2.8- 7.3)	4.3 (2.1- 7.1)	0.641
HOMA (uUI/mL)	1.0(0.8–1.4)	1.1(0.8–1.4)	1.0(0.8–1.5)	1.1(0.7–1.4)	0.918
Hemoglobin (g/dL)	12.4(11.8–13.0)	12.5(12–13.3)	12.1(11.6–12.8)	12.5(11.8–13.0)	0.01
Glycated hemoglobin %,	5(4.8–5.2)	5.0(4.9–5.2)	5.1(4.7–5.3)	5.0 (4.8–5.2)	0.25
Fasting insulin (uUI/mL)	5(4–7)	6(4–8)	5(4–8)	5(4–7)	0.703
Cholesterol (mg/dL)	170(150.8–191)	169(154–187.5)	169(148–192)	172(149–194)	0.645
HDL-c (mg/dL)	58(51–67)	58(52–66)	58.5(48–70)	57.5(51–66)	0.124
LDL-c (mg/dL)	91(76 -107)	92(74 -106)	88(73 -106)	91(77 -107)	0.852

Table 4 (continued)

Variables	Overall	Gestational Weight Gain-Intergrowth-21st Standards			*P*value
		Within	Below	Above	
		81(14.2)	104 (18.3)	384 (67.5)	
Triglycerides (mg/dL)	99(80–118)	95(82.5–115)	102(82.3–116)	98(77–119)	0.654

Data are presented as number (percentage) and median and interquartile range (percentile 25—percentile 75)

Statistical differences among gestational weight gain groups were tested with: Kruskal–Wallis test for continuous variables and χ2 test, Fisher's test for categorical variables

1 Brazilian Real (R$) ≡ 4.9US$

Abbreviations: *BMI* body mass index, *LDL-c* low density lipoprotein cholesterol, *HDL-c* high-density lipoprotein cholesterol. 1º tertile: < 33.3%, 2º tertile: ≥ 33.3%; ≤ 66.6% and 3º tertile: ≥ 66.6%

GWG and their impact on the risk of gestational diabetes. The results showed that the use of Intergrowth-21st classified a higher proportion of women as having GWG above the 90th percentile [26].

The use of different instruments allows us to observe GWG in a more in-depth manner. For instance, the IOM recommendations have some limitations, including the fact that they are based on a specific population from the United States and rely on cross-sectional studies, limiting their applicability [20]. The Intergrowth-21st standards uses a multiethnic cohort of healthy mothers from eight countries, including Brazil, and provide a useful reference for assessing appropriate GWG [22]. This highlights the importance of considering the differences between existing instruments when interpreting the results.

According to the IOM recommendations, the predictors of GWG were height, pre-pregnancy obesity, body fat percentage, diabetes, smoking, number of individuals per room, and number of previous pregnancies. The predictors of GWG based on the Intergrowth-21st standards were height, body fat percentage, and hemoglobin. Comparing the two instruments, both height and body fat percentage had an impact on GWG.

Our results are consistent with studies conducted in Brazil that used the IOM recommendations [16, 18, 19, 29]. A study with pregnant women from the Pelotas cohort showed a prevalence of adequate GWG of 30.9%, with 47% of women being overweight or obese before pregnancy [18]. Another study involving the same cohort revealed a rapid increase in the prevalence of GWG above the recommended range among lower-income women over a period of 30 years (1982–2015). The prevalence of insufficient GWG ranged from 41% in 1982 to 30.8% in 2015, while the prevalence of excessive GWG ranged from 24.6% to 35.7% over the same period in a sample of 19,931 women [19]. A study conducted in Maringá, Paraná state, Brazil, found a prevalence of excessive GWG of 38.3% among 462 pregnant women [29]. Similar findings have been reported in the study by Rodrigues et al. [16] on 173 pregnant women from Rio de Janeiro, Brazil; 44% had insufficient GWG and 22% had excessive GWG. Deputy et al. [17] also found a high prevalence of inadequate GWG (68%) among 44,421 pregnant women living in Switzerland.

The height of the pregnant women was significantly associated with GWG. The tallest women had a higher risk of exceeding the IOM recommendations and Intergrowth-21st standard for GWG, while they were less likely to fall below these guidelines. This finding is consistent with the study by Chiavaroli et al. [30] that analyzed data from over 1 million pregnant women in the United States and found a positive association between maternal height and excessive GWG. Similarly, other studies also showed a positive relationship between maternal height and GWG [19, 31]. Height can influence a woman's ability to accommodate fetal growth and the available space for weight gain during pregnancy [32, 33]. BMI showed significant associations with GWG. Obese women were more likely to exceed the IOM recommendations for GWG. These findings are consistent with Siega-Riz et al. [34] who found that obese women were more likely to exceed the IOM recommendations for GWG compared to women with normal BMI. Similarly, a systematic review and meta-analysis conducted by Voerman et al. [35], which investigated the impact of maternal BMI and GWG on pregnancy complications in European, North American, and Australian cohorts, also reported that obese women had a higher risk of excessive GWG. The review included several studies and concluded that pre-pregnancy obesity was consistently associated with increased GWG. Other studies from low- and middle-income countries also found this relationship between BMI and GWG [31, 32, 36]. The nutritional status of women before conception is reflected by their pre-pregnancy weight, which can affect their weight gain needs during pregnancy [37–39].

Women with two or more previous pregnancies had a lower risk of exceeding the IOM recommendations

Table 5 Crude and adjusted multinomial logistic regression models to assess predictors of GWG, according to the IOM recommendations

Variables	Gestational Weight Gain (IOM-2019)					
	Below	Above	Below	Above	Below	Above
	Crude Model		Adjusted Model A		Final Adjusted Model	
	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)
Age (year)						
20–35	1	1	1	1	1	1
≤ 19	0.97 (0.63—1.47)	0.91(0.6—1.37)	0.79 (0.32–1.90)	1.14 (0.50–2.59)	0.96 (0.57–1.63)	1.09 (0.65–1.83)
> 35	1.09 (0.74—1.6)	1.33(0.92—1.91)	1.16 (0.58–2.33)	1.21 (0.61–2.41)	0.99 (0.63–1.55)	1.22 (0.80–1.87)
Height (cm)						
3º tertile	1	1	1	1	1	1
1º tertile	1.02(0.75—1.4)	0.61(0.46—0.83)	1.65 (0.95–2.87)	0.90 (0.53–1.53)	0.97 (0.68–1.39)	0.57 (0.41–0.80)
2º tertile	1.06(0.77—1.46)	0.74(0.55—1)	1.38 (0.79–2.40)	1.01 (0.60–1.72)	1.02 (0.71–1.47)	0.78 (0.55–1.09)
Pre-gestational BMI (kg /m^2)						
Normal weight	1	1	1	1	1	1
Underweight	1.12 (0.67–1.89)	0.80 (0.44–1.44)	1.91 (0.55–6.60)	2.40 (0.61–9.41)	0.86 (0.41–1.78)	1.26 (0.57–2.80)
Overweight	0.67 (0.49–0.92)	1.58 (1.18–2.12)	0.73 (0.36–1.49)	1.42 (0.72–2.82)	0.84 (0.52–1.36)	1.26 (0.81–1.96)
Obesity	1.34 (0.96–1.87)	2.36 (1.70–3.26)	1.34 (0.55–3.28)	1.92 (0.80–4.57)	1.94 (1.05–3.59)	1.95 (1.08–3.51)
Arm circumference (cm)						
23–28	1	1	1	1	1	1
< 23	0.98(0.54—1.76)	0.7(0.35—1.4)	0.40 (0.10–1.64	0.39 (0.08–1.83)	0.92 (0.41–2.07)	0.54 (0.21–1.37)
> 28	1.8(1.36—2.37)	0.83(0.63—1.09)	0.72 (0.36–1.44)	1.30 (0.63–2.66)	0.79 (0.50–1.26)	1.12 (0.70–1.78)
Body fat %	1.00 (0.98–1.02)	1.05 (1.03–1.07)	1.00 (0.94–1.05)	1.03 (1.01–1.09)	0.98 (0.95–1.02)	1.01 (1.01–1.05)
Gestational age (weeks)	0.89 (0.84–0.95)	1.05 (0.98–1.12)	0.87 (0.80–0.94)	1.11 (1.01–1.22)	0.90 (0.84–0.96)	1.06 (0.98–1.14)
Maternal education (years)						
≥ 12	1	1	1	1	1	1
≤ 4	4.68 (0.54–40.77)	1.07 (0.79–1.44)	1.63 (0.12–22.19)	1.75 (0.13–23.46)	3.47 (0.37–32.83)	2.93 (0.30–28.74)
5–11	2.77 (0.31–25.17)	0.91 (0.68–1.22)	0.62 (0.34–1.13)	0.89 (0.49–1.63)	0.88 (0.61–1.28)	1.01 (0.71–1.45)
Number of people per room						
1º tertile	1	1	1	1	1	1
2º tertile	0.85(0.62—1.16)	1.46(1.08—1.97)	0.97 (0.54–1.74)	1.08 (0.62–1.89)	1.13 (0.78–1.64)	0.88 (0.62–1.25)
3º tertile	0.89(0.66—1.21)	1.07(0.79—1.45)	1.13 (0.62–2.08)	0.91 (0.50–1.65)	1.31 (0.89–1.94)	0.86 (0.59–0.86)
Race						
White	1	1	1	1		
Non-white	1.10 (0.86–1.43)	0.94 (0.73–1.20)	0.92 (0.59–1.46)	0.96 (0.61–1.50)		
Marital status						
Married or in a stable relationship	1	1	1	1		
Single, separated, or widowed	0.93 (0.61–1.44)	0.95 (0.62–1.45)	0.82 (0.41–1.66)	0.72 (0.36–1.46)		
Physical activity						
Adequate	1	1	1	1	1	1
Inadequate	(0.60—1.44)	(0.623—1.454)	0.86 (0.51–1.45)	0.79 (0.48–1.32)	0.94 (0.60–1.60)	0.97 (0.56–1.34)
Smoking	1.37 (0.89–2.10)	0.52 (0.32–0.87)	1.28 (0.63–2.59)	0.55 (0.24–1.25)	1.35 (0.83–2.20)	0.64 (0.37–0.86)
Alcohol consumption	0.98 (0.72–1.34)	0.93 (0.69–1.26)	0.92 (0.55–1.54)	0.91 (0.54–1.52)		
Diabetes	2.44 (1.40–4.27)	0.52 (0.25–1.08)	2.80 (0.94–8.32)	0.26 (0.05–1.45)	2.53 (1.32–4.83)	0.40 (0.16–1.99)
Hypertension	1.19 (0.71–2.00)	1.28 (0.78–2.10)	0.67 (0.26–1.75)	1.37 (0.56–3.36)	0.72 (0.39–1.32)	0.86 (0.48–1.54)
Urinary Tract Infection	1.10 (0.73–1.66)	1.19 (0.81–1.75)	0.76 (0.39–1.48)	1.33 (0.71–2.49)		
Cervicitis/Vaginitis	0.80 (0.49–1.30)	0.72 (0.45–1.16)	1.25 (0.47–3.38)	1.43 (0.52–3.93		
Number of previous pregnancies						
0	1	1	1	1	1	1
1	1.00 (0.73–1.37)	0.72 (0.54–0.98)	1.04 (0.58–1.87)	0.70 (0.39–1.24)	0.83 (0.55–1.25)	0.69 (0.48–1.00)

Table 5 (continued)

Variables	Gestational Weight Gain (IOM-2019)					
	Below	Above	Below	Above	Below	Above
	Crude Model		Adjusted Model A		Final Adjusted Model	
	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)
≥ 2	1.20 (0.88–1.62)	0.77 (0.57–1.03)	0.94 (0.49–1.81)	0.60 (0.32–1.15)	0.83 (0.57–1.25)	0.65 (0.43–0.97)
hs-CRP (ng/mL)	1.01 (0.99–1.02)	1.01 (0.99–1.02)	1.00 (0.98–1.03)	1.00 (0.98–1.03)		
HOMA (uUI/mL)	1.02 (0.93–1.13)	1.03 (0.94–1.13)	0.88 (0.42–1.84)	0.60 (0.25–1.40)		
Hemoglobin (mg/dL)	0.86 (0.75–0.99	1.12 (0.97–1.29)	0.76 (0.62–0.94)	1.01 (0.80–1.25)	0.87 (0.75–1.01)	1.05 (0.91–1.22)
Glycated hemoglobin %	1.01 (0.74–1.40)	0.88 (0.64–1.21)	0.82 (0.50–1.35)	1.22 (0.73–2.03)		
Fasting insulin (uUI/mL)	1.00 (0.98–1.03)	1.01 (0.99–1.03)	1.04 (0.87–1.23)	1.12 (0.93–1.35)	1.00 (0.97–1.02)	0.99 (0.96–1.01)
Cholesterol (mg/dL)	1.00 (0.99–1.00)	1.00 (1.00–1.00)	1.00 (0.97–1.03)	0.97 (0.94–1.00)		
HDL-c (mg/dL)	0.99 (0.98–1.01)	1.01 (1.00–1.02)	0.99 (0.96–1.03)	1.05 (1.01–1.08)	1.00 (0.98–1.01)	1.01 (1.00–1.02)
LDL-c (mg/dL)	1.00 (0.99–1.00)	1.00 (1.00–1.01)	1.01 (0.97–1.04)	1.03 (0.99–1.06)	1.00 (0.99–1.00)	1.00 (0.99–1.00)

Crude Model: the association between each predictor variable and the outcome of interest (GWG)

Adjusted Model A: all predictor variables were adjusted for optimal prediction of GWG, considering their respective strengths

Final Adjusted Model: significant and relevant variables were included based on the theoretical model

1º tertile: < 33.3%, 2º tertile: ≥ 33.3%; ≤ 66.6% and 3º tertile: ≥ 66.6%

Abbreviations: *GWG* gestational weight gain, *BMI* body mass index, *LDL-c* low density lipoprotein cholesterol, *HDL-c* high-density lipoprotein cholesterol, *CI* confidence interval, *OR* odds ratio

for GWG. These findings suggest that prior pregnancy experience may influence women's ability to control their weight gain during this period. One possible explanation is that women with previous pregnancies may be more aware of the importance of maintaining appropriate weight gain during pregnancy. They may have learned from their previous experiences and adopted healthier behaviors.

Pregnant women living in more crowded environments had a lower chance of GWG above the IOM recommendations compared to those living in less crowded homes. This finding may be attributed to the fact that crowded environments are an indicator of unfavorable socioeconomic conditions and limited access to healthcare resources. These factors can negatively affect the diet and lifestyle of pregnant women, resulting in lower GWG [40]. Studies have shown that socioeconomic status is associated with GWG [31, 41, 42].

Among the other significant risk factors investigated, arm circumference and body fat percentage were positively associated with GWG, indicating that women with higher adiposity may have higher weight gain during pregnancy. These findings suggest that maternal nutritional status may be a determinant of GWG. Furthermore, hemoglobin concentrations may reflect maternal nutritional status and overall health, which can potentially affect GWG. These findings suggest a possible relationship between maternal health and appropriate GWG. However, further research is needed to better understand this association and its implications.

Lastly, the presence of diabetes was associated with a higher risk of falling below the GWG recommendations, contradicting previous studies that associated gestational diabetes with excessive weight gain during pregnancy [43–45]. However, these findings are consistent with other studies that have shown a higher prevalence of diabetes or abnormal results in the oral glucose tolerance test among overweight and obese women who gained less than 5 kg compared to those who gained more than 5 kg [46]. Furthermore, a cohort study involving 2,842 pregnant women with diabetes found inadequate GWG to be common, with most participants (50.3%) experiencing insufficient weight gain, followed by adequate (31.6%) and excessive weight gain (18.1%) [47]. This finding can be explained by the need for dietary restriction to control glucose levels, frequent weight monitoring, and the specialized support received by women with gestational diabetes [17, 48, 49]. The risk of ketogenesis, especially in cases of evident hyperglycemia and/or weight loss, is negatively associated with neurocognitive development in children born to mothers with pre-existing diabetes or gestational diabetes [50].

In summary, the findings of this original study provide important insights into the factors associated with GWG and showed that several predictors of inadequate GWG in Brazil were similar to those of high-income countries. We highlight the need for further research on GWG in different populations and contexts, especially low- and middle-income countries, in order to determine the influence of specific factors in other regions of the world

Table 6 Crude and adjusted multinomial logistic regression models to assess predictors of GWG, according to Intergrowth-21st Standards

Variables	Gestational Weight Gain- Intergrowth-21st Standards					
	Below	Above	Below	Above	Below	Above
	Crude Model		Adjusted Model A		Final Adjusted Model	
	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)	OR (IC95%)
Age (year)						
20–35	1	1	1	1	1	1
≤ 19	1.82 (0.82—4.04)	0.99 (0.49—2.01)	1.78(0.82—3.04)	1.40 (0.35–5.65)	1.10 (0.30–4.12)	1.44 (0.39–5.28)
> 35	1.07 (0.41—2.74)	0.95 (0.44—2.07)	4.13 (0.60–28.24)	0.43 (0.10–1.74)	0.85 (0.28–2.62)	0.52 (0.15–1.84)
Height (cm)						
3º tertile	1	1	1	1	1	1
1º tertile	3.32 (1.54—7.12)	1.83 (0.99—3.4)	3.12 (1.75–9.62)	2.68 (0.73–9.90)	2.82 (1.08–8.13)	0.74 (0.26–2.12)
2º tertile	2.07 (1.01—4.25)	1.17 (0.67—2.05)	2.68 (0.49–14.57)	1.96 (0.53–7.25)	1.58 (0.63–3.97)	0.90 (0.35–2.33)
Arm Circumference (cm)						
23–28	1	1	1	1	1	1
< 23	1.35 (0.24—7.66)	1.16 (0.25—5.36)	1.22 (0.82—6.0)	0.84 (0.03–23.30)	1.74 (0.11–2.19)	0.95 (0.04–21.15)
> 28	0.58 (0.31—1.11)	0.7 (0.42—1.17)	1.01 (0.23–4.44)	0.51 (0.15–1.68)	1.20 (0.46–3.15	1.81 (0.69–4.77)
Body fat (%)	0.81 (0.69–0.94)	0.97 (0.84–1.12)	0.88 (0.74–1.04)	0.91 (0.79–1.05)	0.99 (0.90–1.08)	1.12 (1.02–1.24)
Gestational age (weeks)	0.79 (0.70–0.89)	1.07 (0.92–1.24)	0.66 (0.51–0.86)	0.81 (0.62–1.05)	0.83 (0.68–1.02)	1.26 (0.93–1.70)
Maternal education (years)						
≥ 12	1	1	1	1	1	1
< 12	1.15 (0.52–2.52)	1.11 (0.59–2.09)	0.78 (0.13–4.51)	3.18 (0.72–14.04)	0.85 (0.34–2.14)	0.79 (0.30–2.06)
Number of people per room						
3º tertile	1	1	1	1	1	1
1º tertile	0.98 (0.48—2.01)	1.23 (0.69—2.19)	0.53 (0.10–2.83)	0.41 (0.11–1.60)	1.34 (0.50–3.62)	1.38 (0.48–3.95)
2º tertile	1.47 (0.73—2.95)	1.36 (0.75—2.44)	1.34 (0.21–8.45)	0.85 (0.19–3.77)	1.31 (0.50–3.42)	2.30 (0.85–6.23)
Race						
White	1	1	1	1		
Non-white	0.88 (0.49–1.58)	0.97 (0.60–1.58)	0.73 (0.16–3.26)	0.61 (0.17–2.16)		
Marital status						
Married or in a stable relationship	1	1	1	1		
Single, separated, or widowed	1.42 (0.56–3.57)	1.18 (0.53–2.61)	1.16 (0.26–5.14)	1.90 (0.37–9.65)		
Physical activity						
Adequate	1	1	1	1	1	1
Inadequate	0.95 (0.28–3.27)	0.61 (0.22–1.70)	0.80 (0.14–4.66)	0.38 (0.09–1.70)	1.63 (0.68–3.87)	1.03 (0.43–2.47)
Smoking	1.39 (0.39–4.92)	1.57 (0.54–4.60)	0.62 (0.03–10.97)	0.47 (0.03–6.34)	1.63 (0.68–3.87)	2.19 (0.45–10.74)
Alcohol consumption	1.45 (0.67–3.17)	1.51 (0.78–2.93)	1.47 (0.28–7.66)	1.76 (0.44–6.96)		
Number of previous pregnancies						
0	1	1	1	1	1	1
1	3.03 (1.42–6.45)	2.19 (1.13–4.22)	0.81 (0.32–2.09)	3.81 (0.92–5.79)	0.78 (0.32–1.92)	0.52 (0.20–1.31)
≥ 2	1.30 (0.64–2.65)	1.01 (0.91–1.12)	3.61 (0.59–22.12)	1.26 (0.32–4.98)	1.72 (0.59–5.04)	0.96 (0.31–3.00)
hs-CRP (ng/mL)	1.01 (0.97–1.05)	1.00 (0.97–1.04)	1.02 (0.97–1.09)	1.26 (0.32–4.98)		
HOMA (uUI/mL)	0.98 (0.67–1.44)	1.07 (0.79–1.44)	1.73 (0.06–51.17)	1.26 (0.32–4.98)		
Hemoglobin (mg/dL)	0.64 (0.46–0.88)	0.67 (0.35–1.29)	0.55 (0.38–0.79)	0.96 (0.54–1.71)	0.59 (0.39–0.88)	0.78 (0.51–1.20)
Glycated hemoglobin %	1.45 (0.59–3.59)	1.73 (0.82–3.66)	0.41 (0.16–1.06)	1.84 (0.42–8.08)		
Fasting insulin (uUI/mL)	0.98 (0.91–1.06)	1.01 (0.95–1.06)	0.93 (0.46–1.84)	0.70 (0.21–2.31)	0.59 (0.39–0.88)	0.99 (0.90–1.08)
Cholesterol (mg/dL)	1.00 (1.00–1.01)	1.00 (1.00–1.01)	1.07 (1.00–1.15)	1.08 (0.97–1.20)		
HDL-c (mg/dL)	1.00 (0.99–1.01)	1.00 (0.99–1.01)	0.94 (0.87–1.01)	0.90 (0.81–1.01)	0.59 (0.39–0.88)	1.01 (0.98–1.04)
LDL-c (mg/dL)	1.00 (0.97–1.01)	1.00 (0.97–1.0)	0.93 (0.86–1.01)	0.93 (0.83–1.04)	1.01 (0.99–1.02)	0.99 (0.97–1.01)

Crude Model: the association between each predictor variable and the outcome of interest (GWG)

Adjusted Model A: all predictor variables were adjusted for optimal prediction of GWG, considering their respective strengths

Final Adjusted Model: significant and relevant variables were included based on the theoretical model

1º tertile: < 33.3%, 2º tertile: ≥ 33.3%; ≤ 66.6% and 3º tertile: ≥ 66.6%

Abbreviations: *GWG* gestational weight gain, *BMI* Body mass index, *LDL-c* Low density lipoprotein cholesterol, *HDL-c* high-density lipoprotein cholesterol, *CI* confidence interval, *OR* odds ratio

[37, 38, 51, 52]. Furthermore, a recent study on GWG in Brazil by Amorim et al. (2019) provides valuable insights into the prevalence and predictors of GWG, emphasizing the importance of context-specific guidelines and interventions [61].

One limitation of the present study is that we did not assess the pregnant women's dietary intake, which could have provided valuable information on the impact of diet on GWG. However, the study has significant strengths. The prospective cohort approach permits to follow up pregnant women throughout the prenatal period until birth, providing more reliable and detailed data on GWG. The inclusion of a population-based sample also increases the representativeness of the results. Another strength of the study is that GWG is not based on data from the last prenatal visit, as is the case in most studies, but on weight data obtained in the maternity ward shortly before delivery.

Therefore, this original study provides important insights into maternal characteristics and predictors associated with GWG in a Brazilian population. The findings may help guide public health policies and intervention strategies aimed at promoting adequate GWG during pregnancy. However, the limitations mentioned must be considered when interpreting and generalizing the results of the study.

Conclusion

This study is the first to assess predictors of GWG using both the IOM recommendations and the Intergrowth-21st standards in a low- or middle-income country population. The findings identified several maternal predictors of inadequate GWG among Brazilian pregnant women. According to the IOM recommendations, key predictors of GWG included maternal height, pre-pregnancy BMI, body fat percentage, number of individuals per room, smoking, diabetes, and the number of previous pregnancies. For the Intergrowth-21st standards, the main predictors were maternal height, body fat percentage, and hemoglobin concentrations.

These results enhance our understanding of the maternal characteristics associated with inadequate GWG and provide valuable information for the planning of targeted interventions and health policies. Policymakers and healthcare providers should consider these predictors when designing programs to promote adequate GWG. Such programs could include nutritional counseling, targeted support for women with high pre-pregnancy BMI or high body fat percentage, and specific strategies for managing diabetes during pregnancy.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-024-06749-9.

Supplementary Material 1.

Acknowledgements
We would like to express our special gratitude to the professionals, undergraduate, and graduate students who collaborated in the data collection of the Araraquara Cohort Study and to Dr Walter Manso Figueiredo for allowing us to carry part of our study at the Serviço Especial de Saúde de Araraquara, USP.

Authors' contributions
The authors' contributions were as follows AV and PHCR: conceptualization, methodology, formal analysis, and data curation. PHCR: funding acquisition and supervision. LAL, LFC, LDB, LT, PPA and PHCR: investigation. PHCR: project administration. AV and PHCR: visualization and writing—original draft. AV, LAL, LFC, LDB, PPA and PHCR: writing—review and editing. All authors contributed to the article and approved the submitted version.

Funding
This study was supported by the São Paulo Research Foundation (FAPESP) (grant number 2015/03333–6). AV, LFST, LFC and LDB had scholarships from the Coordination for the Improvement of Higher Education Personnel (CAPES). PPA had a scholarship from FAPESP (2018/17824–0).

Availability of data and materials
The datasets produced during this study will be accessible upon request directed to the corresponding author.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was approved by the Research Ethics Committee with Human Subjects at the School of Public Health, University of São Paulo, prior to data collection, under protocol number CAEE: 59787216.2.0000.5421. All participants provided informed consent, consistent with the principles outlined in the Helsinki Declaration.

Competing interests
The authors declare no competing interests.

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Received: 19 April 2024 Accepted: 9 August 2024
Published online: 03 September 2024

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