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ORIGINAL ARTICLE

Pregestational body mass index, trimester-specific weight gain and total gestational weight gain: how do they influence perinatal outcomes?

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ABSTRACT

Objective: To investigate the association between pre-gestational body mass index (BMI), total gestational weight gain (GWG), and/or trimester-specific weight gain (GWGT) with adverse maternal or perinatal outcomes (AMPOs).

Materials and methods: Maternal clinical characteristics and pregnancy and perinatal outcomes were used to predict AMPOs. The predictive ability of BMI, GWG, or GWGT for AMPOs was analyzed using the area under the curve (AUC). Logistic regression models in a univariate and multivariate analysis were performed to estimate the odds ratios (OR) and 95% confidence intervals (CI) to predict maternal outcomes (pregnancy-induced hypertension, preeclampsia or gestational diabetes mellitus) and perinatal outcomes (small for gestational age, large for gestational age, 5-min Apgar score, admission to neonatal intensive care unit or umbilical cord pH <7.15).

Results: Women with AMPOs ($n=293$) were younger with higher rate of nulliparity ($p<.001$) and with lower height ($p=.018$) as compared to controls ($n=134$). In the univariate study, GWGT in third trimester was associated with double risk of pregnancy-induced hypertension (OR 2.00; 95% CI, 1.01–3.97). Nonetheless, third-trimester GWG and total GWG have a negative relationship with gestational diabetes mellitus OR 0.32 (95% CI, 0.18–0.58) and OR 0.35 (95% CI, 0.21–0.59), respectively. Women with greater overall and in second trimester, GWG have a lower risk of having SGA neonates, OR 0.62 (95% CI, 0.39–0.98) and OR 0.60 (95% CI, 0.37–0.98), respectively. In the multivariate study, pre-gestational BMI is strongly related to the development of preeclampsia and the area under the curve (AUC) of the combination of pre-gestational BMI and total weight gain was 0.832 (95% CI, 0.63–0.81) for preeclampsia and 0.719 (95% CI, 0.71–0.94) for gestational diabetes mellitus.

Conclusion: Our results suggest than timing of gestational weight gain influence in maternal and perinatal outcomes. Pre-gestational BMI is a determinant of preeclampsia, maternal weight gain in the third trimester is a determinant of pregnancy-induced hypertension and the increase in total GWG reduces the risk of gestational diabetes mellitus and small for gestational age.

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Gestational weight gain; maternal and neonatal outcomes; obesity; pre-gestational body mass index; pregnancy

Introduction

Worldwide, overweight and obesity are an increasing problem affecting over a third of the world's population today. If secular trends continue, by 2030, an estimated 38% of the world's adult population will be overweight and another 20% will be obese [1]. In recent years, maternal pre-gestational body mass index (BMI) has increased among women of childbearing age in developed countries. In Europe, it is estimated that up to 50% of the adult population is overweight or obese and only 2% is underweight [2]. Among pregnant women, the European prevalence of obesity is between 1.8 and 25.3% [3], a wide range due to the heterogeneity of socio-demographic characteristics and different levels of welfare among countries.

The increasing prevalence of obesity in women of reproductive age will affect obstetric outcomes. There is increasing evidence that pre-gestational BMI and total gestational weight gain (GWG) are risk factors for the development of maternal and perinatal complications [4,5].

Some studies suggest an association between maternal pre-gestational BMI and complications during

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pregnancy, delivery, and the postpartum period for both mother and offspring [6,7], including hypertensive disorders in pregnancy [8], gestational diabetes mellitus (GDM) [9], induction of labor, postpartum hemorrhage (PPH) [10], cesarean section [11] and maternal, perinatal, and infant deaths [12].

Other studies have shown that increasing GWG is associated with higher risk of gestational hypertension [13], preeclampsia [14], and cesarean section [15]. Also, some studies have shown the association with neonatal outcomes such as low birthweight [16,17], low Apgar score or admission to the neonatal intensive care unit (NICU) [18].

However, there are a few studies that relate the trimester-specific GWG and maternal or neonatal outcomes. Therefore, this study aimed to investigate the association between pre-gestational BMI, trimester-specific and total GWG as continuous risk factors associated with comorbidities.

Materials and methods

We retrospectively collected data from 427 deliveries in the Miguel Servet University Hospital (Zaragoza, Spain) from December 2014 to February 2015. An observational study regarding pre-gestational BMI, trimester-specific, and total GWG and maternal and perinatal outcomes was performed.

The inclusion criteria were gestational age at birth over 37 weeks and singleton pregnancy with follow-up at least from 12 weeks. The exclusion criteria were chronic hypertension, pre-gestational diabetes mellitus, antepartum fetal death, and scheduled cesarean section.

In this study, all pregnant women were measured for the height and weight at their first antenatal visit following Fattah et al. [19] recommendations who concluded that maternal mean weight and body composition remained practically constant in the first trimester. BMI was further categorized into four groups: underweight ($<18.5\,kg/m^2$), normal weight ($18.5–24.9\,kg/m^2$), overweight ($25.0–29.9\,kg/m^2$) and obese ($>30.0\,kg/m^2$). GWG (kg) was calculated by subtracting maternal first antenatal visit weight from maternal weight at delivery. The trimester-specific GWG was calculated by subtracting the weight at the beginning of the trimester from the weight at the end of the trimester.

We explored the predictive ability of trimester-specific weight gain and the total GWG combined or not with pre-gestational BMI to diagnose different adverse maternal and perinatal outcomes (AMPOs). The predictors are analyzed as continuous variables and the AMPOs considered were GDM (having at least two plasma glucose values elevated on the 100 g glucose tolerance test), pregnancy induced hypertension (PIH) (systolic blood pressure >140 mmHg or diastolic blood pressure >90 mmHg after 20th week of gestation), preeclampsia (blood pressure $>140/90$ or increases of 30 mmHg of the systolic blood pressure or 15 mm Hg of the diastolic blood pressure or 20 mm Hg of the mean arterial blood pressure, which is accompanied by proteinuria and/or edema after 20th week of gestation), premature rupture of membranes (PROM), PPH, shoulder dystocia, operative vaginal delivery, cesarean section, umbilical cord pH <7.15, admission to NICU, 5-min Apgar score, small for gestational age (SGA) (birth weight <10th percentile) and large for gestational age (LGA) (birth weight >90th percentile) [20].

A univariate and multivariate analysis was performed using logistic regression model. The predictive model was assessed through discrimination analysis using the area under the curve (AUC) and the odds ratio were estimated. The data were analyzed using Research Language programing version 3.3.2 (the R Foundation for Statistical Computing, Vienna, Austria) [21].

Results

Pregnancies characteristics

Table 1 shows the descriptive characteristics of 427 studied pregnant women Median age was 33 years, with a 58% rate of nulliparity. The median value of BMI was 23.1 and 25% and 75% quartiles were 20.9 and 26.4 respectively. Regarding AMPOs, the prevalence was 68.7% in the entire population, infants with a 5-min Apgar score <7 represented 0.5%, percentages of instrumental delivery or cesarean section were, respectively 20.1 and 9.4%, arterial cord blood pH <7.15, 7.7%, PIH 2.3%, preeclampsia 1.9%, and GDM 6.8%.

Pre-gestational BMI, specific-trimester weight gain and total gestational weight gain

Table 2 shows the univariate analysis of the predictive ability of pre-gestational BMI, trimester-specific weight gain and total weight gain to predict adverse perinatal outcomes.

In relation to PE, it was observed that the development of this disease during pregnancy was mainly related to pre-pregnancy BMI. The risk of suffering PE

Table 1. Descriptive characteristics of study population.

Characteristics	$n = 427$
Clinical characteristics	
Maternal age (years)	33 (30, 35)
Maternal body mass index (kg/m^2)	23.1 (20.9, 26.4)
Maternal height (cm)	163 (159, 168)
Paternal height (cm)	176 (172, 181)
Parity	
0	248 (58.1%)
1	149 (34.09%)
≥2	30 (7.0%)
Previous abortions	
0	301 (70.5%)
1	95 (22.2%)
≥2	31 (7.3%)
Previous cesarean	
0	396 (92.7%)
≥1	31 (7.3%)
Maternal ethnicity	
Caucasian	393 (90.0%)
Asian	4 (0.9%)
African	30 (9.1%)
Maternal smoking habits	
Yes	58 (13.6%)
No	369 (86.4%)
Newborn gender	
Female	208 (48.7%)
Male	219 (51.3%)
Specific-trimester weight gain	
1st trimester	0.8 (−0.3, 2.1)
2nd trimester	5.0 (3.5, 6.8)
3rd trimester	5.8 (4.0, 8.3)
Total weight gain	11.8 (9.0, 15.0)
Delivery and perinatal outcomes	
Gestational age at birth (weeks)	40.0 (39.1, 40.7)
Birth weight (grams)	3330 (2990, 3670)
Pregnancy induced hypertension	10 (2.3%)
Preeclampsia	8 (1.9%)
Gestational diabetes mellitus	29 (6.8%)
Premature rupture of membranes	109 (25.5%)
Instrumental delivery	86 (20.1%)
Cesarean section	40 (9.4%)
Postpartum hemorrhage	9 (2.1%)
Shoulder dystocia	9 (2.1%)
Small for gestational age	34 (8%)
Large for gestational age	54 (12.6%)
Apgar score ≤7 (5 minutes)	2 (0.5%)
Neonatal intensive care unit	22 (5.2%)
Postpartum pH <7.15	33 (7.7%)

was increased by 2 at higher pre-gestational BMI (OR 2.00; 95% CI, 1.21–3.33).

Weight gain in first trimester has a significant association with instrumental delivery (OR 1.34; 95% CI, 1.02–1.76). With weight gain in first trimester, no statistically significant association was found with any of the maternal variables under study. The same happened with weight gain in second trimester, except for PROM in which a significant association was obtained with a lower risk (OR 0.73; 95% CI, 0.56–0, 97). An increased risk of PIH was observed in the third trimester (OR 2.00; 95% CI, 1.01–3.97). GWG in third trimester (OR 0.32; 95% CI, 0.18–0.58) and the total weight gain (OR 0.35; 95% CI, 0.21–0.59) were protective factors for the development of GDM. No statistically significant association was found neither for postpartum hemorrhage nor for shoulder dystocia.

Total GWG is a protective factor for the development of a SGA (OR 0.62; 95% CI, 0.39–0.98) and a risk factor for a large fetus for gestational age (OR 1.40; 95% CI, 0.99–1.98). No statistically significant association was found for the rest of the perinatal results.

As it can be seen in Table 3, built predictive models have a moderate discrimination ability to predict AMPOs, except for PE and GDM. The AUC of the combination of pre-gestational BMI and total weight gain was 0.832 (95% CI, 0.63–0.81) for PE and 0.719 (95% CI, 0.71–0.94) for GDM that can be considered a good discrimination ability (Figure 1). Pre-gestational BMI and GWG have a nonlinear relation with preeclampsia adjusted using restricted cubic splines.

Discussion

The mean total weight gain in this study was 12.17 ± 4.83 kg, which is within the weight range recommended by the Institute of Medicine (IOM) for pregnant women with normal pre-gestational BMI, but lower than the average weight (14–15.1 kg) of other studies in European population [22,23].

In the research conducted by Sekiya et al. [24], the average weight gain in the first trimester was 2.3 ± 2.1 kg, in the second trimester 7.0 ± 2.0 kg and in the third trimester 6.3 ± 2.4 kg. These results are similar to those of the present study in the mean weight gain of the third trimester (6.14 ± 3.31 kg) but higher in the gain of the first trimester (0.91 ± 2.09 kg) and of the second (5.14 ± 2.66 kg). The weight gain of the first trimester in the present study, although it may seem scarce, is within the range recommended by the IOM between 0.5 and 2 kg [25].

The percentage of women with pre-gestational BMI < 18.5 kg/m^2 (2.58%) was similar to other European countries [26] but lower than Asian population, where the prevalence of thinness is higher (14–17%) [27,28]. The prevalence of overweight and obesity in our population, 24.82 and 9.60%, respectively, is similar than global average in developed countries [26]. According to other studies, as pre-gestational BMI increases, GWG decreases, both globally and per trimester [17].

This study demonstrates the usefulness of pre-pregnancy BMI, total weight gain and trimester-specific weight gain as risk predictors of AMPOs: preeclampsia, pregnancy-induced hypertension, gestational diabetes mellitus, and large for gestational age.

Table 2. Univariate analysis of the predictive ability of pre-gestational body mass index, trimester-specific weight gain and total weight gain to predict adverse maternal and perinatal outcomes.

Outcome		Pre-gestational body mass index	Gestational weight gain 1st trimester	Gestational weight gain 2nd trimester	Gestational weight gain 3rd trimester	Total gestational weight gain
Adverse maternal outcomes						
PIH	OR AUC	1.33 (0.73–2.42) 0.644	0.88 (0.43–1.76) 0.539	1.06 (0.48–2.30) 0.494	2.00 (1.01–3.97) 0.634	1.61 (0.79–3.29) 0.626
Preeclampsia	OR AUC	2.00 (1.21–3.33) 0.808	0.90 (0.41–1.96) 0.554	1.63 (0.70–3.81) 0.632	1.01 (0.41–2.50) 0.500	1.26 (0.55–2.90) 0.565
Gestational diabetes mellitus	OR AUC	1.64 (1.15-2-33) 0.620	0.68 (0.45–1.03) 0.569	0.84 (0.52–1.34) 0.537	0.32 (0.18–0.58) 0.723	0.35 (0.21–0.59) 0.715
PROM	OR AUC	0.83 (0.63–1.10) 0.540	1.20 (0.94–1.54) 0.551	0.73 (0.56–0.97) 0.574	0.99 (0.74–1.31) 0.516	0.93 (0.71–1.22) 0.517
Postpartum hemorrhage	OR AUC	1.58 (0.92–2.73) 0.595	0.67 (0.33–1.34) 0.583	0.50 (0.22–1.15) 0.561	0.85 (0.35–2.06) 0.538	0.54 (0.23–1.28) 0.614
Instrumental delivery	OR AUC	1.01 (0.76–1.34) 0.493	1.34 (1.02–1.76) 0.588	1.09 (0.81–1.46) 0.511	1.04 (0.77–1.41) 0.514	1.23 (0.92–1.65) 0.534
Cesarean section	OR AUC	1.20 (0.84–1.70) 0.559	1.17 (0.81–1.70) 0.536	1.36 (0.91–2.03) 0.589	1.07 (0.71–1.63) 0.534	1.34 (0.91–1.99) 0.587
Adverse perinatal outcomes						
Shoulder dystocia	OR AUC	0.62 (0.22–1.74) 0.572	1.26 (0.60–2.64) 0.555	1.00 (0.44–2.26) 0.500	0.97 (0.41–2.30) 0.506	1.10 (0.49–2.47) 0.552
Small for gestational age	OR AUC	0.87 (0.55–1.35) 0.553	0.87 (0.58–1.26) 0.561	0.67 (0.43–1.05) 0.585	0.88 (0.55–1.41) 0.534	0.62 (0.39–0.98) 0.599
Large for gestational age	OR AUC	1.16 (0.84–1.60) 0.515	1.22 (0.88–1.69) 0.525	1.36 (0.95–1.93) 0.557	1.05 (0.73–1.52) 0.511	1.40 (0.99–1.98) 0.553
5-min Apgar <7	OR AUC	0.89 (0.54–1.46) 0.541	0.81 (0.49–1.34) 0.553	0.92 (0.53–1.61) 0.534	1.56 (0.83–2.93) 0.549	1.16 (0.66–2.04) 0.528
NICU	OR AUC	0.29 (0.02–4.76) 0.668	1.37 (0.30–6.32) 0.621	0.89 (0.16–5.05) 0.529	1.08 (0.18–6.34) 0.501	1.16 (0.21–6.24) 0.539
Umbilical cord pH < 7.15	OR AUC	1.32 (0.80–2.17) 0.548	1.06 (0.71–1.58) 0.522	0.71 (0.46–1.10) 0.579	1.04 (0.65–1.66) 0.529	0.87 (0.56–1.35) 0.506

PIH: pregnancy induced hypertension; PROM: premature rupture of membranes; NICU: neonatal intensive care unit.

Table 3. Predictive multivariate model according to pre-gestational body mass index, trimester-specific weight gain and total weight gain to predict adverse maternal and perinatal outcomes.

Outcome	Pre-gestational BMI	Gestational weight gain 1st Trimester	Gestational weight gain 2nd Trimester	Gestational weight gain 3rd Trimester	AUC	Body mass index	Total GWG	AUC
Adverse maternal outcomes								
PIH	1.56 (0.80–3.05)	0.84 (0.44–1.62)	1.29 (0.61–2.72)	2.23 (1.10–4.55)	0.673	1.54 (0.81–2.93)	1.77 (0.88–3.56)	0.676
Preeclampsia	2.48 (1.38–2.44)	0.95 (0.48–1.89)	2.11 (0.93–4.77)	1.44 (0.58–3.59)	0.801	2.34 (1.34–4.11)	1.76 (0.79–3.90)	0.832
Gestational diabetes mellitus	1.35 (0.92–1.99)	0.76 (0.49–1.16)	0.91 (0.55–1.48)	0.35 (0.19–0.65)	0.732	1.28 (0.87–1.90)	0.40 (0.23–0.71)	0.719
PROM	0.76 (0.57–1.03)	1.20 (0.93–1.55)	0.68 (0.50–0.91)	0.92 (0.69–1.23)	0.606	0.80 (0.60–1.07)	0.88 (0.66–1.17)	0.550
Postpartum hemorrhage	1.30 (0.69–2.45)	0.69 (0.33–1.46)	0.54 (0.22–1.34)	0.92 (0.39–2.16)	0.626	1.40 (0.77–2.57)	1.01 (0.42–2.41)	0.667
Instrumental delivery	1.06 (0.78–1.42)	1.34 (1.02–1.75)	1.08 (0.80–1.46)	1.02 (0.75–1.39)	0.586	1.06 (0.79–1.43)	1.25 (0.93–1.69)	0.538
Cesarean section	1.33 (0.92–1.93)	1.16 (0.82–1.66)	1.42 (0.96–2.12)	1.12 (0.73–1.71)	0.620	1.31 (0.90–1.90)	1.44 (0.97–2.13)	0.611
Adverse perinatal outcomes								
Shoulder dystocia	0.61 (0.21–1.75)	1.26 (0.57–2.77)	0.90 (0.38–2.16)	0.91 (0.37–2.13)	0.604	0.62 (0.22–1.77)	1.01 (0.42–2.41)	0.572
Small for gestational age	0.73 (0.45–1.19)	0.82 (0.54–1.25)	0.60 (0.37–0.98)	0.84 (0.52–1.35)	0.606	0.74 (0.46–1.20)	0.56 (0.34–0.93)	0.614
Large for gestational age	1.29 (0.92–1.80)	1.21 (0.88–1.67)	1.41 (0.99–2.00)	1.09 (0.75–1.58)	0.581	1.29 (0.92–1.80)	1.48 (1.04–2.10)	0.571
5 min – Apgar <7	0.91 (0.54–1.52)	0.78 (0.47–1.30)	0.93 (0.53–1.62)	1.56 (0.82–2.95)	0.590	0.92 (0.54–1.54)	1.13 (0.63–2.02)	0.536
NICU	0.27 (0.02–4.65)	1.41 (0.25–7.84)	0.72 (0.10–5.01)	1.01 (0.15–6.78)	0.745	0.29 (0.02–4.80)	1.02 (0.15–6.91)	0.666
Umbilical cord pH <7.15	1.26 (0.76–2.10)	1.09 (0.72–1.64)	0.73 (0.46–1.16)	1.05 (0.65–1.71)	0.590	1.29 (0.77–2.15)	0.92 (0.58–1.45)	0.545

BMI: body mass index; PIH: pregnancy induced hypertension; PROM: premature rupture of membranes; NICU: neonatal intensive care unit.

Preeclampsia and pregnancy induced hypertension

In relation to hypertensive disorders in pregnancy, many factors are involved in its pathogenesis, but both the increase in PE and PIH can be explained by changes in inflammatory mediators by obesity [29].

The present study shows that a high pre-pregnancy BMI is strongly associated with the development of PE. A meta-analysis published in 2016 shows sufficient evidence that excess BMI is significantly associated with an increased risk of preeclampsia. It was associated with overweight (OR 1.73; 95% CI: 1.59–1.87) and obesity (OR 3.15; 95% CI: 2.96–3.35). In our study, we found even higher values, with an OR of 5.9 (95% CI: 1.18-29.68) for overweight, and OR of 6.02 (95% CI: 1.38-26.16) for obesity. Therefore, overweight and obesity can be considered as a predictor of preeclampsia [30].

In PIH, there is an increase in risk according to pre-pregnancy BMI, although it is not significant. However, other studies like Scott-Pillai et al. show ORs for PIH varying between 1.19 (95% CI 1.1–2.3) for women with overweight and 6.6 (95% CI 4.9–8.9) for women with obesity [10].

In addition, in this study, there was found an increase of double risk of PIH with weight gain in the third trimester. Although the association did not reach the statistical significance in the other trimesters, there is a trend in the progressive increase of the risk, being lesser in the first trimester and higher in the second trimester. Similar results were obtained by Gaillard et al. with a significant increase in risk in all trimesters, although with the highest risk in the third trimester (OR 1.27; 95% CI: 1.06–1.51, $p < .01$) [31].

Gestational diabetes mellitus

In addition, a high pre-pregnancy BMI is a recognized risk factor for GDM [10,32], as is also demonstrated in this study, with an almost two-fold increase in the risk of gestational diabetes and several previous studies have shown that women with excessive GWG are at increased risk for GDM [33,34].

Nevertheless, in this study, we found that third-trimester weight gain and total weight gain have a negative relationship with GDM reducing its development by 65 and 60%, respectively. The explanation for these results is uncertain, although a theory could be that management of women with GDM includes dietary counseling, lifestyle modification, regular monitoring of blood sugar levels, and insulin treatment, so that their diet would be modified in such a way that

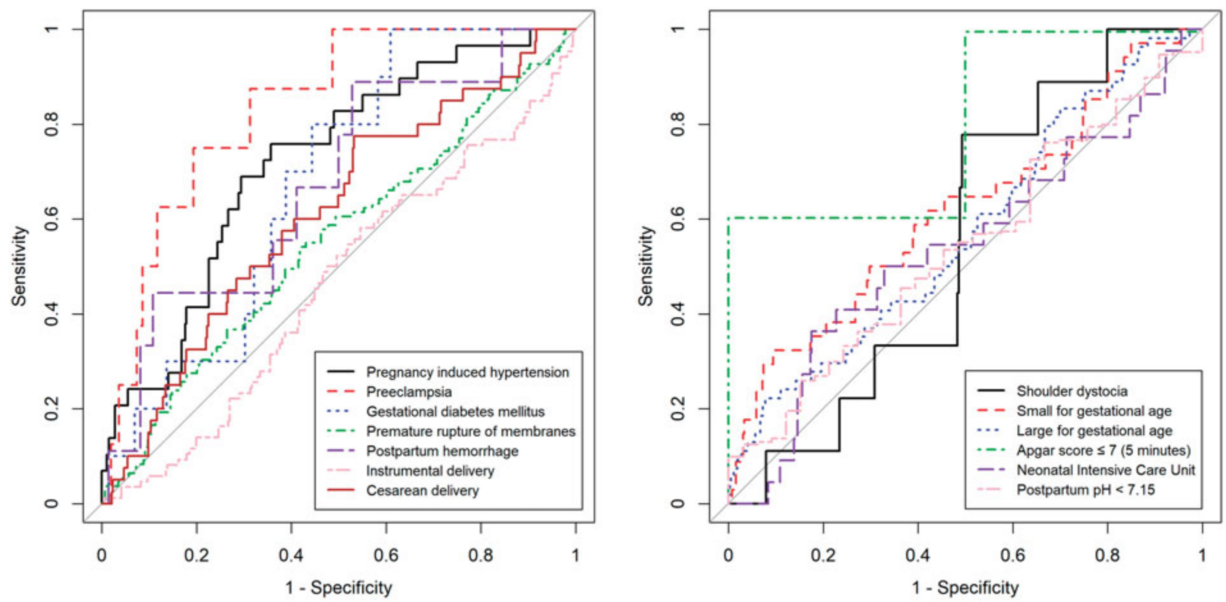

Figure 1. Area under the curve of the predictive capacity of body mass index, gestational weight gain or specific-trimester weight gain for adverse maternal (left) and perinatal outcomes (right).

limits their weight gain [35]. Similar results obtained Dai et al. with a reduction in the risk of diabetes with GWG in the third trimester (OR 0.53; 95% CI: 0.28–0.99) [36].

Neonatal birth weight

Regarding neonatal birth weight, its relationship with pre-gestational BMI and total GWG is clearly demonstrated in the literature [18,37]. There are several studies that establish a positive association between high pre-gestational BMI or total GWG and having LGA neonates [38]. In contrast, low BMI or total GWG increase the risk of SGA [24]. Nevertheless, there are a few studies that analyze specific-trimester weight gain as a risk factor associated with comorbidities [31,36]. In this study, women in the second trimester with a greater overall weight gain have lower risk of having SGA neonates. Also, Gaillard et al. reached similar results reducing the risk of SGA with GWG in each trimester, but obtaining the lowest risk with GWG in the second one. Young et al. [39] studied the relationship of weight gain in three periods of gestation (≤20 weeks, 21–29 weeks, ≥30 weeks) and neonatal birth weight, getting an increase in one standard deviation of weight below 20th week has three times greater influence than compared to the same weight gain from 30th week and it is also associated with a 48% reduction in SGA risk.

Finally, regarding other AMPOs analyzed, previous published studies explored total weight gain during pregnancy rather than trimester weight gain. Gosselink et al. reported that the weight gain during pregnancy was associated with preterm and full term PROM [40], but in our analysis we did not find this relation, only weight gain in the second trimester show association with PROM as a protective factor. In the study of instrumental delivery and cesarean section, only the weight gain during first trimester shown an association with instrumental delivery (OR 1.34), similar to a previous study of Morken et al. (OR 1.2) [41] but in a categorization of total weight gain during pregnancy with a cutoff of 16 kg.

Strengths and limitations

Our study has both strengths and limitations. The data were rigorously collected and the inclusion criteria, women without medical problems, were such that we were able to create a cohort of women at a theoretically low risk of these outcomes. In the great majority of publications, pre-pregnancy weight was self-reported, which is subject to recall error and can lead to under- or overestimation of GWG. The qualitative difference between self-reported data and measured data is debated in several studies [42,43], such as a review by Engstrom et al. [44], which showed that women tend to underestimate their weight and to overestimate their height, which may lead to an incorrect classification of BMI. Also, an analysis of the maternal and perinatal results according to specific-trimester weight increase was made. However, our study was limited by its observational and retrospective design. There might be unmeasured confounders that were not accounted for in this study.

Conclusion

Pre-gestational BMI is clearly associated with the development of PE, increasing the risk to double. The increase in total GWG reduces the risk of GDM and SGA and the increase in weight in the third trimester is associated with the development of PIH. Because of that, it is important to underscore the importance of high quality preconception care to ensure that a woman is in optimal health prior to becoming pregnant and control gestational weight gain particularly in third trimester. In this sense, we recommend of going for an antenatal visit in order to check the BMI for women previous to pregnancy.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

[1] Hruby A, Hu FB. The epidemiology of obesity: a big picture. Pharmacoeconomics. 2015;33:673–689.
[2] Marqués A, Peralta M, Naia A, et al. Prevalence of adult overweight and obesity in 20 European countries, 2014. Eur J Public Health. 2018;28:295–300.
[3] Devlieger R, Benhalima K, Damm P, et al. Maternal obesity in Europe: where do we stand and how to move forward? A scientific paper commissioned by the European Board and College of Obstetrics and Gynaecology (EBCOG). Eur J Obstet Gynecol Reprod Biol. 2016;201:203–208.
[4] Van der Linden EL, Browne JL, Vissers KM, et al. Maternal body mass index and adverse pregnancy outcomes: a Ghanaian cohort study. Obesity 2016;24:215–222.
[5] Truong YN, Yee LM, Caughey AB, et al. Weight gain in pregnancy: does the Institute of Medicine have it right? Am J Obstet Gynecol. 2015;212:362.e1–362.e8.
[6] Ramachenderan J, Bradford J, McLean M. Maternal obesity and pregnancy complications: a review. Aust N Z J Obstet Gynaecol. 2008;48:228–235.
[7] Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382:427–451.
[8] Duckitt K, Harrington D. Risk factors for pre-eclampsia at antenatal booking: systematic review of controlled studies. BMJ. 2005;330:565.
[9] Torloni MR, Betrán AP, Horta BL, et al. Prepregnancy BMI and the risk of gestational diabetes: a systematic review of the literature with meta-analysis. Obes Rev. 2009;10:194–203.
[10] Scott-Pillai R, Spence D, Cardwell CR, et al. The impact of body mass index on maternal and neonatal outcomes: a retrospective study in a UK obstetric population, 2004–2011. Bjog. 2013;120:932–939.
[11] Poobalan AS, Aucott LS, Gurung T, et al. Obesity as an independent risk factor for elective and emergency cesarean delivery in nulliparous women – systematic review and meta-analysis of cohort studies. Obes Rev. 2009;10:28–35.
[12] Yu CKH, Teoh TG, Robinson S. Obesity in pregnancy. BJOG. 2006;113:1117–1125.
[13] Johnson J, Clifton RG, Roberts JM, et al. Pregnancy outcomes with weight gain above or below the 2009 Institute of Medicine guidelines. Obstet Gynecol. 2013;121:969–975.
[14] DeVader SR, Neeley HL, Myles TD, et al. Evaluation of gestational weight gain guidelines for women with normal prepregnancy body mass index. Obstet Gynecol. 2007;110:745–751.
[15] Saftlas A, Wang W, Risch H, et al. Prepregnancy body mass index and gestational weight gain as risk factors for preeclampsia and transient hypertension. Ann Epidemiol. 2000;10:475.
[16] Kiel DW, Dodson EA, Artal R, et al. Gestational weight gain and pregnancy outcomes in obese women: how much is enough? Obstet Gynecol. 2007;110:752–758.
[17] Cedergren M. Effects of gestational weight gain and body mass index on obstetric outcome in Sweden. Int J Gynecol Obstet. 2006;93:269–274.
[18] Stotland NE, Cheng YW, Hopkins LM, et al. Gestational weight gain and adverse neonatal outcome among term infants. Obstet Gynecol. 2006;108:635–643.
[19] Fattah C, Farah N, Barry SC, et al. Maternal weight and body composition in the first trimester of pregnancy. Acta Obstet Gynecol Scand. 2010;89:952–955.
[20] Savirón-Cornudella R, Esteban LM, Lerma D, et al. Comparison of fetal weight distribution improved by paternal height by Spanish standard versus Intergrowth 21st standard. J Perinat Med. 2018;46:750–759.
[21] R Core Team. A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2014. Available from: http://www.R-project.org.
[22] Margerison Zilko CE, Rehkopf D, Abrams B. Association of maternal gestational weight gain with short- and long-term maternal and child health outcomes. Am J Obstet Gynecol. 2010;202:574.e1–574.e8.
[23] Nohr EA, Vaeth M, Baker JL, et al. Combined associations of prepregnancy body mass index and gestational weight gain with the outcome of pregnancy. Am J Clin Nutr. 2008;87:1750–1759.
[24] Sekiya N, Anai T, Matsubara M, et al. Maternal weight gain rate in the second trimester are associated with

birth weight and length of gestation. Gynecol Obstet Invest. 2007;63:45–48.

[25] Institute of Medicine. Weight gain during pregnancy: reexamining the guidelines. Washington, DC: National Academy Press; 2009.

[26] Haugen M, Brantsæter AL, Winkvist A, et al. Associations of pre-pregnancy body mass index and gestational weight gain with pregnancy outcome and postpartum weight retention: a prospective observational cohort study. BMC Pregnancy Childbirth. 2014; 14:201.

[27] Asvanarunat E. Outcomes of gestational weight gain outside the Institute of Medicine guidelines. J Med Assoc Thai. 2014;97:1119–1125.

[28] Choi SK, Park IY, Shin JC. The effects of pre-pregnancy body mass index and gestational weight gain on perinatal outcomes in Korean women: a retrospective cohort study. Reprod Biol Endocrinol. 2011;9:6.

[29] Jeyabalan A. Epidemiology of preeclampsia: impact of obesity. Nutr Rev. 2013;71:S18–S25.

[30] Poorolajal J, Jenabi E. The association between body mass index and preeclampsia: a meta-analysis. J Matern Fetal Neonatal Med. 2016;29:3670–3676.

[31] Gaillard R, Durmuş B, Hofman A, et al. Risk factors and outcomes of maternal obesity and excessive weight gain during pregnancy. Obesity. 2013;21: 1046–1055.

[32] Li N, Liu E, Guo J, et al. Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. Plos One. 2013;8:e82310.

[33] Li C, Liu Y, Zhang W. Joint and independent associations of gestational weight gain and pre-pregnancy body mass index with outcomes of pregnancy in Chinese women: a retrospective cohort study. PLOS One. 2015;10:e0136850.

[34] Saldana TM, Siega-Riz AM, Adair LS, et al. The relationship between pregnancy weight gain and glucose tolerance status among black and white women in central North Carolina. Am J Obstet Gynecol. 2006; 195:1629–1635.

[35] Hung TH, Hsieh TT. The effects of implementing the International Association of Diabetes and Pregnancy Study Groups criteria for diagnosing gestational diabetes on maternal and neonatal outcomes. PLOS One. 2015;10:e0122261.

[36] Dai ZY, Liu D, Li R, et al. Association between gestational weight gain per trimester/total gestational weight gain and gestational diabetes mellitus. Zhonghua Liu Xing Bing Xue Za Zhi. 2016;37: 1336–1340.

[37] Liu Y, Dai W, Dai X, et al. Prepregnancy body mass index and gestational weight gain with the outcome of pregnancy: a 13-year study of 292,568 cases in China. Arch Gynecol Obstet. 2012;286:905–911.

[38] Ferraro ZM, Barrowman N, Prud'homme D, et al. Excessive gestational weight gain predicts large for gestational age neonates independent of maternal body mass index. J Matern Fetal Neonatal Med. 2012; 25:538–542.

[39] Young MF, Hong Nguyen P, Addo OY, et al. Timing of gestational weight gain on fetal growth and infant size at birth in Vietnam. PLOS One. 2017;12: e0170192.

[40] Gosselink CA, Ekwo EE, Woolson RF, et al. Dietary habits, prepregnancy weight, and weight gain during pregnancy: Risk of pre term rupture of amniotic sac membranes. Acta obstetricia et gynecologica Scandinavica. 1992;71(6):425–438.

[41] Morken NH, Klungsøyr K, Magnus P, et al. Pre-pregnant body mass index, gestational weight gain and the risk of operative delivery. Acta obstetricia et gynecologica Scandinavica. 2013;92(7):809–815.

[42] Brunner Huber LR. Validity of self-reported height and weight in women of reproductive age. Matern Child Health J. 2007;11:137–144.

[43] Spencer EA, Appleby PN, Davey GK, et al. Validity of self-reported height and weight in 4808 EPIC-Oxford participants. Public Health Nutr. 2002;5: 561–565.

[44] Engstrom JL, Paterson SA, Doherty A, et al. Accuracy of self- reported height and weight in women: an integrative review of the literature. J Midwif Womens Health. 2003;48:338–345.