Associations between pre-pregnancy body mass index and gestational weight gain with pregnancy outcomes in women with polycystic ovary syndrome

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Research

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Abstract

Background

Polycystic ovary syndrome (PCOS), a reproductive endocrine disorder affecting females of childbearing age, is associated with poor pregnancy outcomes. Both inappropriate pre-pregnancy body mass index (BMI) and gestational weight gain (GWG) could affect the perinatal outcomes in general pregnant women, which raises the question whether various BMI or GWG has impact on pregnancy outcomes in PCOS women. Therefore, we conducted a retrospective study in 722 PCOS women to explore the associations between pre-pregnancy BMI and GWG with pregnancy outcomes among PCOS women with the view of generating vital information that can guide weight management in this group of individuals.

Methods

A retrospective study was conducted targeting baseline characteristics, laboratory data and pregnancy outcomes in 722 singleton pregnant women. We performed multivariable logistic regression analysis to investigate the relationship between BMI and GWG with perinatal outcomes after controlling for appropriate confounding factors.

Results

Our results showed that being underweight were increased the risk of small for gestational age (SGA), but reduced the risk of large for gestational age (LGA). In addition, we found overweight but not obesity individuals were more susceptible to develop preeclampsia compared those with normal weights. For PCOS women with BMI◻25 kg/m^2 before pregnancy, inadequate GWG was a protective factor for gestational hypertension and postpartum hemorrhage(PPH). However, excessive GWG increased the possibility of LGA birth in individuals with BMI◻25 kg/m^2 . Excessive GWG also increased the chances of undergoing a cesarean section in individuals with BMI ≥ 25 kg/m^2. Inadequate GWG didn't reduce the risk of LGA for women with BMI ≥ 25 kg/m^2, similarly, excessive GWG didn't decrease the chance of delivering SGA infant for women with BMI◻25 kg/m^2.

Conclusion

The impacts of pre-pregnancy BMI, GWG on maternal and infant outcomes among PCOS women are similar to what has been reported in general pregnant women. However, some unique trends exist in PCOS women. Overall, these findings indicate that women with PCOS need to begin weight management before pregnancy.

Background

Polycystic ovary syndrome (PCOS), a common heterogeneous female endocrinopathy affecting approximately 5 to 20% of women of childbearing age worldwide (1), is characterized by

hyperandrogenemia, hyperinsulinemia, and insulin resistance (2). In recent years, advancement in assisted reproductive technology has significantly increased chances of pregnancy in PCOS women. However, this condition has increased the risk of complications during pregnancy or delivery, such as prevalence of gestational diabetes mellitus (GDM), preeclampsia, and premature delivery (3). For example, women with PCOS are more prone to be overweight/obese and to experience higher GWG, than their normal counterparts (4, 5). GWG in women is crucial to optimize maternal, fetal, and neonatal health, with previous studies associating inappropriate pre-pregnancy BMI and GWG were at higher risks of adverse neonatal and maternal outcomes in general pregnant women (6–11). However, few studies have described the impact of both pre-pregnancy BMI and GWG on maternal and infant outcomes of this special individuals. In light of this, our study attempted to access the effect of pre-pregnancy BMI and GWG on pregnancy outcomes of PCOS women, with a view of generating vital information to guide proper weight management before or during pregnancy and reduce related adverse maternal and infant outcomes.

Materials And Methods

Characteristics of the study population

The present study was a retrospective cohort study comprising 722 PCOS women who established a medical record for receiving healthcare at the first trimester of pregnancy and delivered live-born singletons at the Beijing Obstetrics and Gynecology Hospital, Capital Medical University between July, 2017 and July, 2019. Participants were included in the study if they; (i) were women diagnosed with PCOS; (ii) were pregnant; (iii) were aged between 18 and 45 years; and (iv) had a singleton pregnancy. On the other hand, subjects were excluded if they; (i) were females with multiple pregnancies; (ii) had pre-existing hypertension or chronic diseases; (iii) exhibited fetal chromosomal abnormalities or major birth defects and; (iv) did not have complete clinical data. The study received ethical approval from the ethics committee of the Beijing Obstetrics and Gynecology Hospital affiliated with Capital Medical University, with all the participants signing informed consent documents prior to inclusion.

Methods

We used the hospital's electronic medical record system to collect patient-level variables, such as standard demographic information (age, pre-pregnancy height and weight, GWG, number of prior pregnancies, husband age, abnormal pregnancy history and family history) and relevant maternal and infant outcomes as well as laboratory data. Then, the associations between maternal pre-pregnancy BMI, GWG clinical categories and risk of some perinatal outcomes among PCOS women, which have been rarely investigated, were explored in our study.

Maternal pre-pregnancy BMI classifications

Pre-pregnancy BMI, calculated as weight before pregnancy divided by height squared, was used to categorize the subjects into 4 groups, according to World Health Organization (WHO)'s guidelines. Based

on these criteria, individuals with a BMI of < 18.5, 18.5−24.9, 25.0-29.9 and ≥ 30 kg/m^2, were classified as underweight, normal weight, overweight and obese, respectively.

Maternal GWG classifications

Maternal GWG, calculated as weight before delivery minus pre-pregnancy weight, was used to group the subjects into within or above the target as recommended by the Institute of Medicine (IOM). According to these guidelines, different weight gain intervals exist based on the pregestational BMI (Table 1). Weight gains of 12.5−18, 11.5−16, 7−11.5 and 5−9 kilograms are recommended for underweight, normal weight, overweight and obese women, respectively. Gestational weight gains below or above the recommendation threshold were defined as inadequate or excessive weight gains, respectively.

Pregnancy outcomes

We examined the following pregnancy outcomes: Gestational hypertension (12), preeclampsia (13), GDM (based on the result of a standard 75gram oral glucose tolerance test between 24−28 weeks of gestation), PPH (blood loss ≥ 500 mL within 24 hours of delivery), SGA (a birth weight☐10th percentile for gestational age and gender), LGA (a birth weight☐90th percentile for gestational age and gender), macrosomia (a birth weight ≥ 4000 g), cesarean section, vaginal delivery, and assisted vaginal delivery (forceps or vacuum and assisted breech delivery).

Statistical analyses

All data were evaluated using SPSS 23.0 software, and results presented as means ± standard deviations (SD) of the means. Enumeration data were analyzed using the Chi-square test, whereas multivariable logistic regression analysis were applied to assess the correlation between BMI, and GWG with pregnancy outcomes, after controlling for appropriate confounding factors such as maternal age, height, pre-pregnancy BMI, gravidity, parity, gestational age at delivery, weight gain during pregnancy, cigarette smoke and alcohol consumption pre-pregnancy. Values followed by $P < 0.05$ were considered statistically significant.

Results

Basic characteristics of the research population

Among the 722 patients enrolled in the study, 83.5% primiparas and 16.5% multiparas were analyzed. The study population had an average maternal age of 31.7 ± 6.1 years at enrollment, a mean gestational period of 38.7 ± 1.7 weeks, and an average pre-pregnancy BMI of 23.6 ± 1.7 kg/m^2. In addition, the entire population had a mean GWG of 13.10 ± 4.88 kg, whereas those of underweight, normal weight, overweight and obese individuals were 14.6 ± 4.1, 13.8 ± 4.4, 12.0 ± 5.5 and 9.6±5.5 kg, respectively. Analysis of pregnancy outcomes revealed that 22.6, 12.3, 5.4, and 10.9% of the study subjects had developed GDM, gestational hypertension, preeclampsia and PPH, respectively. With regards to modes of

delivery, 56.8,8.3 and 34.9% of the women required vaginal, assisted vaginal and cesarean section delivery, respectively. Furthermore, 8.7, 1.8 and 18.8% of the newborns were characterized with macrosomia, SGA and LGA, respectively.

The relationship between pre-pregnancy BMI and pregnancy outcomes

Among the 722 subjects, 6.5, 63.7, 21.1 and 8.7 % were underweight, normal weight, overweight, and obese, respectively, prior to pregnancy. Underweight women experienced a higher possibility of SGA birth (OR 12.35, 95% CI 3.56-42.82) and vaginal delivery (OR 2.21, 95% CI 1.09-4.50), compared to women with normal weight before pregnancy. Conversely, underweight was negatively correlated with the risk of LGA (OR 0.21, 95% CI 0.05-0.88) (Table 2). Moreover, overweight and obese PCOS women had a higher risk of developing gestational hypertension (OR 4.86, 95% CI 2.82-8.39; and OR 6.05, 95% CI 2.97-12.33, respectively), undergoing cesarean section (OR 1.71, 95% CI 1.15-2.55; and OR 2.10, 95% CI 1.18-3.74, respectively), and having an infant with LGA (OR 2.57, 95% CI 1.64-4.04; and OR 2.22, 95% CI 1.12-4.39, respectively) when compared with normal weight women. On the other hand, overweight women were more likely to develop preeclampsia (OR 4.08, 95% CI 1.95-8.51) and result in macrosomia at birth (OR 2.15, 95% CI 1.14-4.05).

The association between GWG and adverse pregnancy outcomes

According to the IOM guidelines, approximately 23% of women in this study experienced inadequate weight gain, whereas 45 and 32% of them gained the recommended and more than recommended weight, respectively. With regards to the effect of GWG on pregnancy complications (Table 3), 4.1, 13, and 17.4% of women in the inadequate, adequate and excessive GWG groups, respectively, had gestational hypertension, whereas 4.7, 11.8 and 14.3% of those achieved inadequate, adequate and excessive GWG, respectively, developed PPH. Significantly lower (P<0.05) incidences of gestational hypertension and PPH were recorded in the inadequate GWG groups, whereas significantly higher (P<0.001) LGA and macrosomia incidences were recorded in the excessive GWG relative to the other 2 groups. Results from multivariate logistic regression for assessing the relationship between GWG categories with pregnancy outcomes are outlined in Table 4. Specifically, individuals in the inadequate GWG group had a lower risk of developing gestational hypertension（OR 0.28, 95%CI 0.12-0.66）and PPH（OR 0.38, 95%CI 0.17-0.84), compared to those in the adequate GWG group. On the other hand, those in the excessive GWG group were more likely to deliver macrosomia（OR 1.93, 95%CI 1.05-3.54）and give birth to LGA infants (OR 1.94, 95%CI 1.27-2.96). Subgroup analyses, based on stratification of body mass indices, revealed that inadequate GWG decreased the risks of gestational hypertension（OR 0.24, 95%CI 0.08-0.71) and PPH（OR 0.38, 95%CI 0.16-0.95）in women with BMI ＜25 kg/m^2 before pregnancy(Table 5). Moreover, excessive GWG was significantly related to the higher possibility of LGA birth（OR 2.41, 95%CI 1.40-4.18）in women with BMI ＜25kg/m^2 as well as chances of undergoing a cesarean section（OR 2.06, 95%CI 1.01-4.20）in women with BMI ≥25kg/m^2 (Table 6).

Table 1
Recommendations for total weight gain during pregnancy, by pregnancy body mass index, according to the guidelines of the Institute of Medicine and National Research Council (2009).

Pre-pregnancy Weight category	Body Mass Index (kg/m^2)	Recommended Range of Total Weight (kg)
Underweight	<18.5	12.5−18.0
Normal Weight	18.5−24.9	11.5−16.0
Overweight	25.0-29.9	7.0-11.5
Obese	≥ 30	5.0−9.0

Table 2
The relationship among BMI categories and maternal/fetal outcomes

Outcome	Underweight Adjusted OR (95% CI)	Normal Weight Adjusted OR (95% CI)	Overweight Adjusted OR (95% CI)	Obesity Adjusted OR (95% CI)
Gestational hypertension	0.24[0.03−1.80]	1	4.86[2.82−8.39]**	6.05[2.97−12.33]**
Preeclampsia	0.55[0.07−4.29]	1	4.08[1.95−8.51]**	1.46[0.40−5.37]
Gestational diabetes	0.56[0.21−1.51]	1	1.33[0.85−2.09]	1.23[0.65−2.32]
Postpartum hemorrhage	0.18[0.02−1.35]	1	1.60[0.91−2.81]	1.88[0.83−4.24]
Cesarean section	0.55[0.25−1.20]	1	1.71[1.15−2.55]*	2.10[1.18−3.74]*
Assisted vaginal delivery	0.36[0.08−1.56]	1	0.50[0.23−1.12]	0.41[0.12−1.42]
Vaginal delivery	2.21[1.09−4.50]*	1	0.75[0.51−1.09]	0.65[0.37−1.14]
Macrosomia	0.46[0.10−2.07]	1	2.15[1.14−4.05]*	1.54[0.52−4.55]
SGA	12.35[3.56−42.82]**	1	0.41[0.05−3.62]	NS
LGA	0.21[0.05−0.88]*	1	2.57[1.64−4.04]**	2.22[1.12−4.39]*

OR = odds ratio; CI = confidence interval; SGA = small for gestational age; LGA = large for gestational age; NS = the number in this category was too small to analyze;

Data was analyzed using multivariable logistic regression analysis. Models were adjusted for maternal age, height, gravidity, parity, gestational age at delivery, weight gain during pregnancy, cigarette smoke pre-pregnancy and alcohol consumption pre-pregnancy.

Reference group: normal weight for pre-pregnancy

* $p < 0.05$; ** $p < 0.001$;

Table 3
The relationship between maternal/fetal outcomes and GWG

Outcome	Inadequate GWG (N = 169)	Adequate GWG (N = 323)	Excessive GWG (N = 230)	p-Value
Gestational hypertension (N)	7(4.1%)	42(13%)	40(17.4%)	<0.001
Preeclampsia (N)	5(3%)	17(5.3%)	17(7.4%)	0.15
Gestational diabetes	64(37.9%)	69(21.4%)	30(13%)	<0.001
Postpartum hemorrhage (N)	8(4.7%)	38(11.8%)	33(14.3%)	0.008
Cesarean section (N)	56(33.1%)	108(33.4%)	88(38.3%)	0.43
Assisted vaginal delivery (N)	14(8.3%)	30(9.3%)	16(7.0%)	0.62
Vaginal delivery (N)	99(58.6%)	185(57.3%)	126(54.8%)	0.73
Macrosomia (N)	7(4.1%)	22(6.8%)	34(14.8%)	<0.001
SGA (N)	4(2.4%)	5(1.5%)	4(1.7%)	0.72
LGA (N)	18(10.7%)	53(16.4%)	72(31.3%)	<0.001
SGA = small for gestational age; LGA = large for gestational age; N = number of cases.				

Table 4

The relationship between GWG categories and pregnancy outcomes

Outcome	Inadequate GWG Adjusted OR p-Value (95% CI)	Excessive GWG Adjusted OR p-Value (95% CI)
Gestational hypertension	0.28[0.12−0.66] 0.003	1.15[0.69−1.91] 0.59
Preeclampsia	0.56[0.20−1.56] 0.26	1.36[0.66−2.78] 0.41
Gestational diabetes	2.30[1.49−3.54] <0.001	0.49[0.30−0.80] 0.004
Postpartum hemorrhage	0.38[0.17−0.84] 0.02	1.21[0.73−2.04] 0.46
Cesarean section	0.88[0.58−1.34] 0.56	1.28[0.88−1.87] 0.19
Assisted vaginal delivery	0.97[0.49−1.92] 0.93	0.64[0.34−1.24] 0.19
Vaginal delivery	1.13[0.76−1.67] 0.55	0.91[0.64−1.29] 0.58
Macrosomia	0.67[0.27−1.66] 0.39	1.93[1.05−3.54] 0.03
SGA	1.23[0.31−4.87] 0.77	1.25[0.32−4.95] 0.75
LGA	0.65[0.36−1.17] 0.15	1.94[1.27−2.96] 0.002
OR = odds ratio; CI = confidence interval; SGA = small for gestational age; LGA = large for gestational age		

Data was analyzed using multivariable logistic regression analysis. Models were adjusted for maternal age, height, gravidity, parity, gestational age at delivery, pre-pregnancy BMI, as well as pre-pregnancy cigarette smoke and alcohol consumption.

Reference group: adequate GWG group

Table 5

Pregnancy outcomes among women whose weight gain was below levels recommended by guidelines of the Institute of Medicine

Outcome	BMI<25 kg/m^2		BMI ≥ 25 kg/m^2	
	Adjusted OR (95% CI)	p-Value	Adjusted OR (95% CI)	p-Value
Gestational hypertension	0.24[0.08−0.71]	0.01	0.27[0.05−1.33]	0.11
Preeclampsia	0.62[0.19−2.01]	0.42	NS	
Gestational diabetes	2.55[1.54−4.23]	<0.001	2.16[0.87−5.38]	0.10
Postpartum hemorrhage	0.38[0.16−0.95]	0.04	0.22[0.02−1.95]	0.17
Cesarean section	0.83[0.52−1.33]	0.43	0.94[0.38−2.34]	0.89
Assisted vaginal delivery	0.88[0.42−1.84]	0.73	1.18[0.14−10.02]	0.88
Vaginal delivery	1.23[0.79−1.92]	0.35	1.06[0.43−2.63]	0.90
Macrosomia	0.78[0.28−2.14]	0.63	0.26[0.02−3.37]	0.30
SGA	1.43[0.36−5.67]	0.61	NS	
LGA	0.54[0.25−1.16]	0.11	1.05[0.34−3.23]	0.93

OR = odds ratio; CI = confidence interval; SGA = small for gestational age; LGA = large for gestational age; NS = the number in this category was too small to analyze;

Data was analyzed using multivariable logistic regression analysis. Models were adjusted for maternal age, height, gravidity, parity, gestational age at delivery, cigarette smoke pre-pregnancy and alcohol consumption pre-pregnancy.

Reference group: adequate GWG in the same BMI category

Table 6
Pregnancy outcomes among women whose weight gain was above recommended levels

Outcome	BMI <25 kg/m^2		BMI ≥ 25 kg/m^2	
	Adjusted OR (95% CI)	p-Value	Adjusted OR (95% CI)	p-Value
Gestational hypertension	0.43[0.17−1.11]	0.08	1.85[0.86-4.00]	0.12
Preeclampsia	0.48[0.13−1.79]	0.27	2.08[0.69−6.32]	0.20
Gestational diabetes	0.31[0.14−0.72]	0.006	0.56[0.27−1.17]	0.12
Postpartum hemorrhage	1.15[0.57−2.30]	0.70	1.50[0.70−3.21]	0.29
Cesarean section	0.94[0.57−1.54]	0.80	2.06[1.01−4.20]	0.048
Assisted vaginal delivery	0.88[0.42−1.83]	0.72	0.43[0.07−2.74]	0.37
Vaginal delivery	1.10[0.70−1.73]	0.69	0.56[0.28−1.12]	0.10
Macrosomia	1.90[0.87−4.17]	0.11	2.17[0.69−6.79]	0.19
SGA	1.29[0.28−5.82]	0.74	NS	
LGA	2.41[1.40−4.18]	0.002	1.53[0.73−3.23]	0.26

OR = odds ratio; CI = confidence interval; SGA = small for gestational age; LGA = large for gestational age; NS = the number in this category was too small to analyze;

Data was analyzed using multivariable logistic regression analysis. Models were adjusted for maternal age, height, gravidity, parity, gestational age at delivery, cigarette smoke pre-pregnancy and alcohol consumption pre-pregnancy.

Reference group: adequate GWG in the same BMI category

Discussion

Our results revealed a positive association between women who were underweight, prior to pregnancy, with incidence of SGA infants and a negative relationship between this group of women with incidence of LGA infants. We also found that pre-pregnancy overweight but not obesity were more susceptible to suffer preeclampsia. Furthermore, GWG below the recommended level significantly reduced the risk for gestational hypertension and PPH in women with pre-pregnancy BMI < 25 kg/m^2, whereas that above the

recommended threshold increased chances of cesarean section in those with a pre-pregnancy BMI $\geq$ 25 kg/m^2. For women with BMI$\geq$25 kg/m^2, GWG below the recommendation didn't reduce the chance of LGA and GWG above the recommendation didn't show protective effect on SGA birth in women with BMI < 25 kg/m^2.

Our findings further indicated that pre-pregnant underweight PCOS women were at a higher risk of SGA but at a lower risk for LGA, relative to normal weight PCOS counterparts. Particularly, underweight PCOS women had a 12-fold risk of having SGA than normal weight counterparts, which was much higher than general underweight women（OR 1.67, 95%CI 1.49-1.87）(14). PCOS in pregnancy can involve elevated androgen concentration level which might affect fetal outcomes(15). Thus, the superposition effect of PCOS and underweight state may contribute to this result. Furthermore, GWG over the recommendation didn't show any protective effects in SGA birth for women with BMI（25 kg/m^2. Instead, they exhibited a significantly positive correlation with birth of LGA infants compared with GWG within the IOM guidelines in the same BMI category. Therefore, these results indicate that women with BMI（25 kg/m^2 may need to adhere to IOM guidelines to obtain optimal fetal growth, since higher weight gain does not guarantee better pregnancy outcomes.

In the present study, both overweight and obesity conditions increased the risk of gestational hypertension, but showed different effects on preeclampsia. Specifically, preeclampsia was associated with overweight but not obese women, which was contrary to previous reports. For example, a study conducted in Belgium found no significant differences in the prevalence of gestational hypertension and preeclampsia between overweight and normal weight PCOS women (16), possibly due to differences in races and potential confounders. On the other hand, a study on general Chinese pregnant women revealed that underweight, overweight and obese conditions increased the risk of GH (6), but they didn't explore whether various BMI has impact on developing preeclampsia. Our results revealed that both overweight and obese PCOS women were more likely to give birth to LGA infants, whereas maternal overweight condition increased the risk of macrosomia when compared with normal weight women. However, we did not find a significant relationship between obesity and macrosomia, consistent with a previous retrospective study found that high BMI had no significant impact on the risk of delivering LGA newborn or macrosomia, in PCOS women who underwent frozen embryo transfer (17). A study on general pregnant Chinese women found that overweight and obese women were more prone to have LGA and macrosomia compared to normal weight counterparts (18). A possible explanation for this phenomenon may be that different ways of conception have certain effects on pregnancy outcomes.

Based on the IOM guidelines of 2009，45% of the PCOS women in the present study achieved adequate weight gain during pregnancy, which was higher than previously reported frequencies, including 29.6 and 30% in general and PCOS women, respectively (19) (20). This may be attributed to strict management regimes given to PCOS women at our hospital. Specifically, once PCOS women became pregnant, they were admitted to a specialized outpatient section where they received individualized Medical nutritional therapy (MNT) as well as exercise guidance to help control weight gain during pregnancy.

We evaluated the effect of different GWG on PCOS women with BMI≥25 kg/m^2, However, no relationship was found between various GWG and fetal growth in this BMI group. The result is possibly related to the sample size in our study. On the other hand, GWG may play a relative weak role in fetal growth. Therefore, it prompts us that more efforts should be shifted to pre-conceptional weight management in PCOS women to achieve a normal weight. Previous studies have shown that overweight /obesity and PCOS are risk factors for GDM (21, 22). In addition, early evidence suggests that clinical features of PCOS, such as polycystic ovaries, insulin resistance and hyperandrogenism, might be potential factors of the GDM (23). In the present study, we found high incidence of GDM in overweight (30.2%) and obese (36.5%) PCOS women, relative to normal weight (19.8%) counterparts, however, with no statistical significance following multivariate regression analysis. Such result may be related to intervention for PCOS women before or during pregnancy. What's more, different diagnostic criteria and presence of heterogeneity between study populations may contribute to this finding.

From our results, it is evident that inadequate GWG is a protective factor for gestational hypertension and PPH in women with pregestational BMI◻25 kg/m^2, relative to those whose weight gain is within the optimal range in the same BMI category. However, we found no impact on overweight and obese pregnant women, indicating that GWG has different effects on gestational hypertension and PPH across different BMI groups. In future, large sample sized and multi-center studies are expected to validate these findings. Our results also indicated a positive relationship between excessive GWG and incidence of cesarean section in women with BMI ≥ 25 kg/m^2, relative to those with weight gain within the IOM guidelines in the same BMI category. This was consistent with a previous study that associated high GWG with cesarean delivery in women with obesity class I (BMI 30.0-34.9 kg/m^2) compared to those who met gestational weight gain goals (24). However, for women with BMI ≥25 kg/m^2, inadequate GWG didn't reduce the risk for LGA birth, which was consistent with our previously mentioned result showing that excessive GWG didn't play a protective role in delivering an SGA newborn in women with BMI◻25 kg/m^2. Our finding was contrary to previous studies on general pregnant women(6, 25). It is possible that the small number of SGA cases in our study was the reason for the observed result. Besides this, whether factors of complicated endocrine and metabolism in PCOS is at work deserves further investigation. Moreover, we found an inverse relationship between GWG and GDM, when PCOS women were diagnosed with GDM at 24–28 weeks' gestation, in line with previous studies (6) (26). To control weight gain and blood sugar levels, these women may undergo MNT, acquire exercise guidance and insulin therapy when necessary, hence the real association between GWG and GDM may have been masked. Therefore, further research is required to confirm the relationship between weight gain and development of GDM among pregnant women with PCOS at different pregnancy periods.

Our study had several limitations. First, our participants' pre-pregnancy body weights were self-reported, at the first visit (week 6-8 or so). It is possible that recall bias may have occurred, thereby affecting evaluation of BMI and GWG. Second, our study population mainly comprised subjects from the Beijing area, indicating that our findings may not reflect individuals from other Chinese regions or countries,

owing to potential differences in education, socio-economic levels, as well as varying environmental factors.

Conclusions

Our findings indicated that inappropriate pre-pregnancy BMI and GWG are associated with higher risk of adverse maternal/infant outcomes. Furthermore, GWG exerted a different effect on perinatal outcomes among women across different BMI categories. The correlations, between pre-pregnancy BMI, GWG and pregnancy outcomes among PCOS women, observed herein were similar to what has been reported in general women. However, some unique trends exist in PCOS women. Specifically, being underweight are more likely to deliver an SGA baby, overweight but not obesity is correlated with the risk for preeclampsia. Conversely, overweight or obese conditions are not associated with GDM, whereas inadequate GWG is a protective factor for gestational hypertension and PPH only in pregestational BMI⬚25 kg/m^2. Inadequate GWG did not reduce the possibility of LGA birth in women with BMI≥25 kg/m^2 and excessive GWG did not decrease the risk for SGA in women with BMI⬚25 kg/m^2. In general, pre-pregnancy BMI and GWG has different impact on pregnancy outcomes between general and PCOS pregnant women. Taken together, these findings suggest that management/intervention for PCOS women should focus on pre-conceptional weight management. Future studies are expected to elucidate the ideal pre-pregnancy weight and ascertain methods for appropriate weight gain during pregnancy.

Abbreviations

PCOS
Polycystic ovary syndrome
BMI
Body mass index
GWG
Gestational weight gain
SGA
Small for gestational age
LGA
Large for gestational age
PPH
Postpartum hemorrhage
GDM
Gestational diabetes mellitus
WHO
World Health Organization
IOM
Institute of Medicine

MNT
Medical nutritional therapy
OR
Odds ratio
CI
Confidence interval
SD
standard deviations

Declarations

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Authors' contributions

All the authors contributed significantly to the manuscript. LRZ was primarily responsible for the data analysis and writing of the manuscript. WZ significantly revised the draft, interpreted the data, and involved in data analyses. CL and XL collected the information and participated in data interpretation. LZ and ZHT involved in the data management and draft revision. GHL was responsible for designing the study and critically revising the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

The data is available upon reasonable request to the corresponding author.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Beijing Obstetrics and Gynecology Hospital (2012-KY-012, 2016-KY-066). Written informed consent was obtained from all participants. All procedures were performed in compliance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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