Original Article

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Association of pre-pregnancy body mass index and gestational weight gain with pregnancy outcomes

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Background: Gestational weight gain (GWG) is a modifiable risk factor for pregnancy outcomes. This study aimed to evaluate the associations of pre-pregnancy body mass index (BMI) and GWG with perinatal and maternal outcomes in Hong Kong women and to identify risk factors for poor perinatal/maternal outcomes.

Methods: Medical records of low-risk women with singleton pregnancy who delivered babies between 1 January 2019 and 28 February 2019 at our hospital were reviewed. Based on pre-pregnancy BMI, women were categorised as underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), pre-obesity (25-29.9 kg/m^2), and obesity (>30 kg/m^2). Based on the recommended total GWG by the Institute of Medicine, women were categorised as inadequate, normal, and excessive GWG. The normal group was compared with each of the other groups.

Results: 465 women were included for analysis. Of them, 439 (94.4%) delivered after 37 weeks of gestation and 26 (5.6%) delivered before 37 weeks of gestation. After adjusting for confounders, the risk factors for gestational diabetes were women with pre-obesity (odds ratio [OR]=3.879, p=0.001) and women with obesity (OR=15.118, p<0.001), whereas the risk factor for neonatal ventilator use was women with pre-obesity (OR=5.719, p=0.035) and the risk factor for caesarean section was women with excessive GWG (OR=1.591, p=0.047).

Conclusion: High pre-pregnancy BMI is associated with gestational diabetes and neonatal ventilator use, whereas excessive GWG is associated with caesarean section.

Keywords: Body mass index; Gestational weight gain; National Academies of Science, Engineering, and Medicine, U.S., Health and Medicine Division; Pregnancy outcome

Introduction

The importance of pre-pregnancy nutritional status and gestational weight gain (GWG) is increasingly recognised. Pre-pregnancy underweight is associated with low birth weight and preterm delivery, whereas obesity is associated with gestational diabetes, hypertensive disorder, and macrosomia. Inadequate or excessive GWG has persistent negative impact to offspring on cardiometabolic risks such as childhood adiposity, hypertension, and insulin resistance. Health counselling based on the body mass index (BMI) status is not adequate. GWG is a modifiable risk factor for adverse pregnancy outcomes. Nonetheless, the optimal GWG remains controversial. In 2009, the United States Institute of Medicine proposed a guideline on GWG (Table 1)[1]. Whether this guideline applies to the Chinese population is not known. This study aimed to evaluate the associations of pre-pregnancy BMI and GWG with perinatal and maternal outcomes in Hong Kong women and to identify risk factors for poor perinatal/maternal outcomes.

Materials and Methods

This study was approved by the Kowloon Central Cluster Research Ethics Committee (reference: KC/KE-21-0210/ER-1). Medical records of low-risk healthy Chinese women with singleton pregnancy who were followed up and delivered at Queen Elizabeth Hospital between 1 January 2019 and 28 February 2019 were retrospective reviewed. The hospital is a tertiary public hospital in Hong Kong, with live births around 5000 to 6000 per year.

Exclusion criteria were (1) non-Chinese couples, (2) women with pre-existing medical conditions (diabetes, hypertension, thyroid disease, autoimmune disease, history of malignancy, cardiac disease, epilepsy, liver disease, kidney disease, or other systemic condition), (3) women with a history of substance abuse, (4) smokers, (5) women with negative outcomes in previous pregnancies (low birth weight, macrosomia, intrauterine death, fetal anomaly, placenta pathology, preterm delivery, gestational diabetes, gestational hypertensive disorder, postpartum haemorrhage, severe neonatal complication), (6) women with fetal or placental pathology in the current pregnancy, (7) women with multiple pregnancies or intrauterine death, and (8) women with incomplete follow-up and delivery data.

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Table 1. Total gestational weight gain recommended by the US Institute of Medicine[1]

Body mass index, kg/m^2	Total gestational weight gain recommended, kg
<18.5 (underweight)	12.5-18
18.5-24.9 (normal weight)	11.5-16
25-29.9 (pre-obesity)	7-11.5
>30 (obesity)	5-9

Material characteristics retrieved included maternal age, gravida, parity, previous caesarean section, education level, working status, family history of diabetes mellitus, family history of hypertension, assisted reproductive technology, maternal height, and body weight and BMI before pregnancy, at 20 to 24 weeks of gestation, and at delivery. Early GWG was defined as body weight at 20 to 24 weeks of gestation minus pre-pregnancy body weight. Late GWG was defined as body weight at delivery minus body weight at 20 to 24 weeks of gestation. Total GWG was defined as body weight at delivery minus pre-pregnancy body weight.

Pregnancy and neonatal outcomes retrieved included low birth weight, macrosomia, preterm birth, modes of delivery, primary postpartum haemorrhage, gestational diabetes, gestational hypertensive disorder, maternal peripartum fever, neonatal intensive care unit admission, neonatal sepsis, need for neonatal resuscitation, neonatal respiratory distress syndrome, transient tachypnoea of the newborn, need for ventilator support, neonatal jaundice, neonatal necrotising enterocolitis, hypoxic-ischemic encephalopathy, neonatal seizure, meconium-stained liquor, and obstetric anal sphincter injury.

Analyses were performed using SPSS (Windows version 26; IBM Corp, Armonk [NY], US). A p value of <0.05 was considered statistically significant. Based on pre-pregnancy BMI, women were categorised as underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), pre-obesity (25-29.9 kg/m^2), and obesity (>30 kg/m^2). Based on the recommended total GWG by the Institute of Medicine, women were categorised as inadequate, normal, and excessive GWG. The normal group was compared with each of the other groups using the unpaired sample t-tests or ANOVA for continuous data and the Chi-square test or Fisher exact test for categorical data. Multivariate analysis was used to adjust the effect of confounders on adverse maternal and neonatal outcomes.

Results

Of 916 women followed up and delivered during the 2-month study period, 451 were excluded based on the exclusion criteria and 465 were included for analysis. Of them, 439 (94.4%) delivered after 37 weeks of gestation and 26 (5.6%) delivered before 37 weeks of gestation. In terms of pre-pregnancy BMI, 61 (13.1%) women were underweight, 329 (70.8%) women were normal weight, 60 (12.9%) women were pre-obese, and 15 (3.2%) women were obese. In terms of total GWG, 157 (33.8%) women were inadequate, 194 (41.7%) women were normal, and 114 (24.5%) women were excessive.

Association of maternal demographics with pre-pregnancy BMI

Compared with women with normal weight, women with underweight were younger (29.33 vs 30.28, p=0.020), and women with obesity were older (31.60 vs 30.28, p=0.005), and women with pre-obesity had a higher parity (0.55 vs 0.35, p=0.009) and more caesarean sections (0.17 vs 0.05, p=0.048) [Table 2]. Women with normal weight had the highest percentage of tertiary education, compared with women with underweight, pre-obesity, or obesity (72.3% vs 55.7% vs 51.7% vs 40%, p=0.016 to p=0.001), and had higher percentage of being employed, compared with women with obesity (53.5% vs 82.7%, p=0.01).

Association of pre-pregnancy BMI with GWG

Compared with women with normal weight, women with pre-obesity had a lower percentage of normal GWG (26.7% vs 42.6%, p=0.021), whereas women with underweight had a lower percentage of excessive GWG (9.8% vs 23.1%, p=0.020) and women with pre-obesity had a higher percentage of excessive GWG (46.7% vs 23.1%, p<0.001) [Table 2].

Association of maternal demographics with GWG

Compared with women with normal GWG, women with excessive GWG were younger (29.43 vs 30.29 years, p=0.013), had a lower percentage of tertiary education (57% vs 71.6%, p=0.009) and had a higher pre-pregnancy BMI (22.817 vs 21.195 kg/m^2, p<0.001) [Table 3].

Association of pre-pregnancy BMI with pregnancy outcomes

The percentage of gestational diabetes was highest in women with obesity (46.7%), followed by women with pre-obesity (18.3%), compared with women with normal weight (5.5%) [p<0.001 and p=0.002, respectively]. Gestational diabetes was associated with a

Table 2. Maternal characteristics and pregnancy outcomes among women with normal weight, underweight, pre-obesity, or obesity

Characteristic	Normal weight (n=329)*	Underweight (n=61)*	p Value	Pre-obesity (n=60)*	p Value	Obesity (n=15)*	p Value
Age, y	30.28±2.901	29.33±3.048	**0.020**	30.33±2.660	0.900	31.60±1.502	**0.005**
Parity	0.35±0.554	0.38±0.610	0.697	0.55±0.565	**0.009**	0.53±0.516	0.201
Gravida	1.71±0.954	1.72±0.933	0.903	1.95±0.964	0.069	2.07±1.223	0.157
Previous caesarean section	0.05±0.228	0.10±0.351	0.213	0.17±0.418	**0.048**	0.13±0.352	0.405
Maternal height, cm	159.4±5.7	159.7±4.9	0.679	158.6±5.2	0.296	159.2±5.5	0.888
Tertiary education	238 (72.3)	34 (55.7)	**0.010**	31 (51.7)	**0.001**	6 (40.0)	**0.016**
Employment	272 (82.7)	44 (72.1)	0.054	44 (73.3)	0.088	8 (53.3)	**0.010**
Assisted reproductive technology	12 (3.6)	1 (1.6)	0.701	1 (1.7)	0.701	2 (13.3)	0.119
Family history of diabetes mellitus	56 (17.0)	14 (23.0)	0.268	19 (31.7)	0.008	3 (20.0)	0.728
Family history of hypertension	114 (34.7)	22 (36.1)	0.831	26 (43.3)	0.198	3 (20.0)	0.241
Gestational weight gain							
Inadequate	113 (34.3)	25 (41.0)	0.319	16 (26.7)	0.245	3 (20.0)	0.250
Normal	140 (42.6)	30 (49.2)	0.338	16 (26.7)	**0.021**	8 (53.3)	0.410
Excessive	76 (23.1)	6 (9.8)	**0.020**	28 (46.7)	**<0.001**	4 (26.7)	0.757
Outcome							
Preterm birth	15 (4.6)	5 (8.2)	0.218	6 (10.0)	0.113	0 (0)	1.000
Caesarean section	74 (22.5)	17 (27.9)	0.410	14 (23.3)	0.886	5 (33.3)	0.349
Maternal complication							
Gestational diabetes	18 (5.5)	3 (7.7)	1.000	11 (18.3)	**0.002**	7 (46.7)	**<0.001**
Gestational hypertensive disorder	9 (2.7)	0 (0)	0.365	2 (3.3)	0.681	0 (0)	1.000
Postpartum haemorrhage	16 (4.9)	2 (3.3)	0.750	4 (6.7)	0.526	0 (0)	1.000
Peripartum fever	25 (7.6)	6 (9.8)	0.605	5 (8.3)	0.795	1 (6.7)	1.000
Neonatal complications							
Low birth weight	16 (4.9)	5 (8.2)	0.348	1 (1.7)	0.489	0 (0)	1.000
Macrosomia	4 (1.2)	1 (1.6)	0.575	1 (1.7)	0.569	1 (6.7)	0.201
Neonatal sepsis	18 (5.5)	4 (6.6)	0.762	3 (5.0)	1.000	1 (6.7)	0.581
Neonatal intensive care unit admission	70 (21.3)	13 (21.3)	0.995	12 (20.0)	0.824	3 (20.0)	1.000
Need of resuscitation	3 (0.9)	0 (0)	1.000	0 (0)	1.000	0 (0)	1.000
Respiratory distress syndrome	7 (2.1)	1 (1.6)	1.000	4 (6.7)	0.073	1 (6.7)	0.303
Transient tachypnoea of the newborn	20 (6.1)	1 (1.6)	0.222	2 (3.3)	0.551	0 (0)	1.000
Need of ventilator support	3 (0.9)	1 (1.6)	0.495	3 (5.0)	**0.018**	0 (0)	1.000
Respiratory complication	24 (7.3)	2 (3.3)	0.400	7 (11.7)	0.296	1 (6.7)	1.000
Neonatal jaundice	131 (39.8)	29 (47.5)	0.260	32 (53.3)	0.051	7 (46.7)	0.597
Meconium stained liquor	31 (9.4)	9 (14.8)	0.207	6 (10.0)	0.888	1 (6.7)	1.000

* Data are presented as mean ± standard deviation or No. (%) of participants

Table 3. Maternal characteristics and pregnancy outcomes among women with normal gestational weight gain (GWG), inadequate GWG, or excessive GWG

Characteristic	Normal GWG (n=194)	Inadequate GWG (n=157)	p Value	Excessive GWG (n=114)	p Value
Age, y	30.29±2.89	30.66±2.69	0.222	29.43±2.96	**0.013**
Parity	0.37±0 .54	0.46±0.61	0.111	0.30±0.51	0.282
Gravida	1.65±0.88	1.82±0.96	0.094	1.83±1.08	0.106
Previous caesarean section	0.08±0.29	0.09±0.30	0.835	0.05±0.22	0.350
Maternal height, cm	159.550±5.24	158.775±5.93	0.195	159.761±5.27	0.735
Tertiary education	139 (71.6)	105 (66.9)	0.334	65 (57.0)	**0.009**
Employment	152 (78.4)	128 (81.5)	0.461	88 (77.2)	0.813
Assisted reproductive technology	8 (4.1)	7 (4.5)	0.877	1 (0.9)	0.162
Family history of diabetes mellitus	40 (20.6)	27 (17.2)	0.417	25 (21.9)	0.785
Family history of hypertension	69 (35.6)	55 (35.0)	0.917	41 (36.0)	0.944
Pre-pregnancy body mass index, kg/m^2	21.195±3.4236	21.493±3.5690	0.426	22.817±4.161	**<0.001**
Preterm birth	7 (3.6)	11 (7.0)	0.151	8 (7.0)	0.180
Caesarean section	45 (23.2)	28 (17.8)	0.218	37 (32.5)	**0.048**
Maternal complications					
Gestational diabetes	15 (7.7)	14 (8.9)	0.688	10 (8.8)	0.747
Gestational hypertensive disorder	4 (2.1)	3 (1.9)	1.000	4 (3.5)	0.474
Postpartum haemorrhage	6 (3.1)	11 (7.0)	0.140	5 (4.4)	0.543
Peripartum fever	16 (8.2)	10 (6.4)	0.504	11 (9.6)	0.674
Neonatal complications					
Low birth weight	7 (3.6)	13 (8.3)	**0.048**	2 (1.8)	0.493
Macrosomia	3 (1.5)	1 (0.6)	0.631	3 (2.6)	0.674
Neonatal sepsis	11 (5.7)	7 (4.5)	0.609	8 (7.0)	0.635
Neonatal intensive care unit admission	40 (20.6)	28 (17.8)	0.512	30 (26.3)	0.249
Need of resuscitation	3 (1.5)	0 (0)	0.256	0 (0)	0.298
Respiratory distress syndrome	6 (3.1)	2 (1.3)	0.305	5 (4.4)	0.543
Transient tachypnoea of the newborn	9 (4.6)	8 (5.1)	0.843	6 (5.3)	0.806
Need of ventilator support	5 (2.6)	1 (0.6)	0.230	1 (0.9)	0.418
Respiratory complication	15 (7.7)	10 (6.4)	0.662	9 (7.9)	0.959
Neonatal jaundice	82 (42.3)	59 (37.6)	0.373	58 (50.9)	0.143
Meconium-stained liquor	21 (10.8)	15 (9.6)	0.696	11 (9.6)	0.744

* Data are presented as mean ± standard deviation or No. (%) of participants

family history of diabetes mellitus (odds ratio [OR]=5.78, p<0.001), early GWG (OR=1.13, p=0.048), and late GWG (OR=0.78, p<0.001) but not total GWG. After adjusting for confounders, gestational diabetes was associated with women with pre-obesity (OR=3.879, p=0.001) and women with obesity (OR=15.118, p<0.001) [Table 4].

The percentage of neonates needing ventilator support was higher in women with pre-obesity, compared with women with normal weight (5.0% vs 0.9%, p=0.018). After adjusting for confounders, the need for neonatal ventilator support was associated with women with pre-obesity (OR=5.71, p=0.035) [Table 4].

Table 4. Multivariate analysis for the association of pre-pregnancy body mass index with gestational diabetes and need for neonatal ventilator support

	Adjusted odds ratio (95% confidential interval)		
	Underweight vs normal weight	Pre-obesity vs normal weight	Obesity vs normal weight
Gestational diabetes*	0.894 (0.255-3.132)	3.879 (1.728-8.704)	15.118 (4.932-46.341)
p Value	0.861	0.001	<0.001
Need for neonatal ventilator support†	1.811 (0.185-17.704)	5.719 (1.126-29.041)	-
p Value	0.610	0.035	

* Adjusted for family history of diabetes and early and total gestational weight gain
† Adjusted for maternal age, preterm birth, and late gestational weight gain

Table 5. Multivariate analysis for the association of gestational weight gain (GWG) with caesarean section and low birth weight

	Adjusted odds ratio (95% confidential interval)	
	Underweight vs normal weight	Obesity vs normal weight
Caesarean section*	0.719 (0.424-1.218)	1.591 (1.241-3.012)
p Value	0.220	0.047
Low birth weight†	2.412 (0.938-6.200)	0.477 (0.097-2.337)
p Value	0.068	0.361

* Adjusted for parity, gravida, number of previous caesarean sections, and maternal height
† Adjusted for maternal height and parity

Association of GWG with pregnancy outcomes

Compared with women with normal GWG, women with excessive GWG had a higher percentage of caesarean section (32.5% vs 23.2%, p=0.048). After adjusting for confounders, excessive GWG was associated with a higher rate of caesarean section (OR=1.591, p=0.047, Table 5).

Compared with women with normal GWG, women with inadequate GWG had a higher percentage of low birth weight babies (8.3% vs 3.6%, p=0.048, Table 3). After adjusting for confounders, the association became not significant (Table 5).

Discussion

Age and education level were associated with pre-pregnancy BMI and total GWG. Age may affect the metabolic rate. Women with higher education levels may have higher awareness of the consequences of an abnormal BMI and GWG and thus had better diet control[2].

The percentage of inadequate GWG was highest in underweight women, whereas the percentage of excessive GWG was highest in pre-obesity women. These findings are consistent with those in previous studies[3,4]. Inadequate and excessive GWG can be associated with diet. The diet quality score was highest in women with normal GWG, and the association between GWG adherence and prenatal diet quality was dependent on pre-pregnancy BMI[4]. This suggests that antenatal interventions such as nutrition counselling may improve diet quality and GWG, particularly in women with pre-obesity or obesity[3-6].

Women with pre-obesity or obesity had higher risk of gestational diabetes. Pre-pregnancy BMI is associated with gestational diabetes[14,15], probably owing to the difference in adipose tissue influences insulin resistance[12,13]. In women with obesity, adipocytes can act as an endocrine factor, releasing adipokines, which can affect oocyte differentiation and maturation[2]. In addition, implantation and reproductive functions are also impaired in women with obesity. Higher early GWG is associated with a higher risk of gestational diabetes[16,17]. Advice for optimal BMI should be provided in pre-conception and antenatal counselling, as high BMI increases the risk of developing type 2 diabetes mellitus. Thus, diet modification and physical activities during and beyond pregnancy are important[14-18].

Women with excessive GWG had a higher rate of caesarean section, whereas women with pre-obesity had a higher rate of neonatal ventilator support. Women with higher GWG have been reported to have a higher risk of emergency caesarean sections and instrumental deliveries[7-11].

The total GWG recommended by the US Institute of Medicine was associated with the mode of delivery only.

An increase in adverse pregnancy outcomes in women with excessive GWG can be due to effects of oxidative stress, pro-inflammatory status, altered placental function, and impaired insulin sensitivity. However, the present study failed to demonstrate such associations, as did other studies[19,20]. The reasons can be due to socioeconomic, medical, cultural, and nutritional differences or the small sample size. The prevalence of obesity is higher in Western countries. Strict inclusion criteria might have eliminated many risk factors of maternal and perinatal complications. Active smokers have a higher risk of preterm delivery, low birth weight, and neonatal respiratory distress syndrome[21]. Advanced maternal age is associated with operative vaginal delivery, caesarean section, preterm birth, low birth weight, and neonatal death[22]. A multicentre study with a larger population is required to verify the applicability of the Institute of Medicine recommendations in Hong Kong Chinese populations. A specialised electronic obstetric system is needed to facilitate data collection and analysis across various hospitals[23].

The present study has limitations. The sample size was too small to determine the optimal GWG range. The number of women with obesity was small. Pre-pregnancy body weight was self-reported. Women with delivery during 24 to 41 weeks of gestation were included; GWG partly depends on the pregnancy duration. Smaller GWG occurs in extreme preterm birth, and smaller babies have more neonatal complications. The reason for including preterm births was to compare the effect of GWG on the risk of preterm delivery. GWG per week was not examined owing to the retrospective nature. The rate of GWG through trimesters may be more accurate. The oral glucose tolerance test is not universally performed in Hong Kong; the prevalence of gestational diabetes may be underestimated. Long-term outcomes of the newborn and mother were not studied.

Conclusion

High pre-pregnancy BMI is associated with gestational diabetes and neonatal ventilator use, whereas excessive GWG is associated with caesarean deliveries.

Contributors

The author designed the study, acquired the data, analysed the data, drafted the manuscript, and critically revised the manuscript for important intellectual content. The author had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

The author has disclosed no conflicts of interest.

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Data availability

All data generated or analysed during the present study are available from the corresponding author on reasonable request.

Ethics approval

The study was approved by the Kowloon Central Cluster Research Ethics Committee (reference: KC/KE-21-0210/ER-1). The patients were treated in accordance with the tenets of the Declaration of Helsinki. The patients provided written informed consent for all treatments and procedures and for publication.

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References

1. Institute of Medicine, Food and Nutrition Board. Committee on Nutritional Status During Pregnancy, part I: Nutritional Status and Weight Gain. Washington: National Academy Press; 2000.
2. Silvestris E, de Pergola G, Rosania R, Loverro G. Obesity as disruptor of the female fertility. Reprod Biol Endocrinol 2018;16:22. Crossref
3. Simko M, Totka A, Vondrova D, et al. Maternal body mass index and gestational weight gain and their association with pregnancy complications and perinatal conditions. Int J Environ Res Public Health 2019;16:1751. Crossref
4. Parker HW, Tovar A, McCurdy K, Vadiveloo M. Associations between pre-pregnancy BMI, gestational weight gain, and prenatal diet quality in a national sample. PLoS One 2019;14:e0224034. Crossref
5. Shin D, Lee KW, Song WO. Pre-pregnancy weight status is associated with diet quality and nutritional biomarkers during pregnancy. Nutrients 2016;8:162. Crossref

6. de Jersey SJ, Mallan K, Callaway L, Daniels, LA, Nicholson JM. A cross sectional comparison of predisposing, reinforcing and enabling factors for lifestyle health behaviours and weight gain in healthy and overweight pregnant women. Matern Child Health J 2017;21:626-35. Crossref
7. Cedergren M. Effects of gestational weight gain and body mass index on obstetric outcome in Sweden. Int J Gynaecol Obstet 2006;93:269-74. Crossref
8. Chung JG, Taylor RS, Thompson JM, et al. Gestational weight gain and adverse pregnancy outcomes in a nulliparous cohort. Eur J Obstet Gynecol Reprod Biol 2013;167:149-53. Crossref
9. 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.e1-8. Crossref
10. Durie DE, Thornburg LL, Glantz JC. Effect of second-trimester and third-trimester rate of gestational weight gain on maternal and neonatal outcomes. Obstet Gynecol 2011;118:569-75. Crossref
11. Thorsdottir I, Torfadottir JE, Birgisdottir BE, Geirsson RT. Weight gain in women of normal weight before pregnancy: complications in pregnancy or delivery and birth outcome. Obstet Gynecol 2002;99:799-806. Crossref
12. Sun Y, Shen Z, Zhan Y, et al. Effects of pre-pregnancy body mass index and gestational weight gain on maternal and infant complications. BMC Pregnancy Childbirth 2020;20:390. Crossref
13. Vrachnis N, Belitsos P, Sifakis S, et al. Role of adipokines and other inflammatory mediators in gestational diabetes mellitus and previous gestational diabetes mellitus. Int J Endocrinol 2012;2012:549748. Crossref
14. Najafi F, Hasani J, Izadi N, et al. The effect of prepregnancy body mass index on the risk of gestational diabetes mellitus: a systematic review and dose-response meta-analysis. Obes Rev 2019;20:472-86. Crossref
15. Kim SY, Sharma AJ, Sappenfield W, Wilson HG, Salihu HM. Association of maternal body mass index, excessive weight gain, and gestational diabetes mellitus with large-for-gestational-age births. Obstet Gynecol 2014;123:737-44. Crossref
16. Hedderson MM, Gunderson EP, Ferrara A. Gestational weight gain and risk of gestational diabetes mellitus. Obstet Gynecol 2010;115:597-604. Crossref
17. Wu Y, Wan S, Gu S, et al. Gestational weight gain and adverse pregnancy outcomes: a prospective cohort study. BMJ Open 2020;10:e038187. Crossref
18. Catalano PM, McIntyre HD, Cruickshank JK, et al. The hyperglycemia and adverse pregnancy outcome study: associations of GDM and obesity with pregnancy outcomes. Diabetes Care 2012;35:780-6. Crossref
19. Ukah UV, Bayrampour H, Sabr Y, et al. Association between gestational weight gain and severe adverse birth outcomes in Washington State, US: a population-based retrospective cohort study, 2004-2013. PLoS Med 2019;16:e1003009. Crossref
20. Eraslan Sahin M, Col Madendag I. Effect of gestational weight gain on perinatal outcomes in low risk pregnancies with normal prepregnancy body mass index. Biomed Res Int 2019;2019:3768601. Crossref
21. Mei-Dan E, Walfisch A, Weisz B, Hallak, M, Brown R, Shrim A. The unborn smoker: association between smoking during pregnancy and adverse perinatal outcomes. J Perinat Med 2015;43:553-8. Crossref
22. Hsieh TT, Liou JD, Hsu JJ, Lo LM, Chen SF, Hung TH. Advanced maternal age and adverse perinatal outcomes in an Asian population. Eur J Obstet Gynecol Reprod Biol 2010;148:21-6. Crossref
23. 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. Crossref
24. Chen CN, Chen HS, Hsu HC. Maternal prepregnancy body mass index, gestational weight gain, and risk of adverse perinatal outcomes in Taiwan: a population-based birth cohort study. Int J Environ Res Public Health 2020;17:1221. Crossref