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Combination of body mass index and body fat percentage in middle and late pregnancy to predict pregnancy outcomes in patients with gestational diabetes in Wenzhou, China: a single-centre retrospective cohort study

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ABSTRACT

Objectives The present study aimed to evaluate whether body mass index (BMI) and body fat percentage (BFP) could be used to predict pregnancy outcomes in patients with gestational diabetes mellitus (GDM).

Design Retrospective cohort study.

Setting Wenzhou Medical University Affiliated Second Hospital (Zhejiang Province, China). Clinical data were collected from electronic medical records.

Participants Data from 683 patients with GDM admitted to the Wenzhou Medical University Affiliated Second Hospital between January 2019 and December 2021 were retrospectively analysed.

Outcome measures Pregnancy outcomes.

Results The results showed that pregnant women with BFP ≥33% were more prone to abnormal amniotic fluid volume, abnormal blood pressure and anaemia (p<0.05). Additionally, these patients were more likely to experience postpartum haemorrhage and macrosomia, as well as risk factors associated with caesarean section at labour (p<0.05). BMI exhibited a strong predictive value for abnormal blood pressure (OR 1.170; 95% CI 1.090 to 1.275), anaemia (OR 1.073; 95% CI 1.016 to 1.134), caesarean section (OR 1.150; 95% CI 1.096 to 1.208) and macrosomia (OR 1.169; 95% CI 1.063 to 1.285). Additionally, classified BFP had a predictive value for abnormal amniotic fluid volume (OR 3.196; 95% CI 1.294 to 7.894), abnormal blood pressure (OR 2.321; 95% CI 1.186 to 4.545), anaemia (OR 1.817; 95% CI 1.216 to 2.714), and caesarean section (OR 1.734; 95% CI 1.270 to 2.367).

Conclusions The results suggest that patients with GDM with BFP ≥33% were more likely to experience unfavourable pregnancy outcomes, undergo caesarean section and develop macrosomia. The combination of BMI with classified BFP could better predict abnormal blood pressure and caesarean section in patients with GDM during the middle and late stages of pregnancy.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This was a retrospective study of pregnancy outcomes in patients with gestational diabetes mellitus.
⇒ This study was conducted at a single centre with a limited sample size.
⇒ The effectiveness of bioelectrical impedance analysis instruments varies by manufacturer, and this study was based solely on the body composition analyser (Inbody770, Korea).
⇒ Other data, such as insulin levels, blood cholesterol levels or visceral fat, were not considered in this study, and only the effect of body mass index and body fat percentage on pregnancy outcomes in the middle and late stages of pregnancy was evaluated.

INTRODUCTION

Diabetes that develops or is initially diagnosed during pregnancy is known as gestational diabetes mellitus (GDM).[1 2] Nowadays, as living standards have improved, the incidence of GDM has increased, especially in younger people, drawing a lot of attention.[3–5] GDM may be associated with some adverse outcomes for mothers and offspring. Short-term adverse outcomes include pre-eclampsia, preterm labour and delivery, primary caesarean delivery, macrosomia, large for gestational-age infants, clinical neonatal hypoglycaemia, shoulder dystocia, birth injuries and perinatal mortality. Long-term adverse outcomes for offspring include higher blood glucose level, insulin resistance and obesity.[6 7] Therefore, evaluating the nutritional status of women during pregnancy is of great importance since the risk factors for GDM, including obesity and abnormal weight gain during pregnancy, are significant.[8] It has been reported that body composition can change during pregnancy, and it can therefore be used as an objective

evaluation standard in clinical practice. However, simply monitoring body weight and body mass index (BMI) does not account for differences in body composition, which has particular limitations.[9 10]

In clinical practice, a number of studies have investigated the impact of body composition on pregnancy outcomes.[11–14] The body fat percentage (BFP) considerably raises during pregnancy and is calculated using the following formula: (fat mass ÷ body mass) × 100%.[15] Previous studies demonstrated that BFP exhibited a prognostic value for GDM during the early and middle phases of pregnancy.[16] Excessive fat accumulation in the body during the early and middle phases of pregnancy is considered a risk factor for the development of GDM, thus resulting in high fat compositions during pregnancy. Therefore, BFP can increase the risk of GDM.[15–17] Additionally, a previous study indicated that BFP exerted a more potent prognostic value in predicting GDM compared with BMI.[18] The body composition during pregnancy can be calculated using traditional techniques, including anthropometry, density measurement and hydrometry.[19 20] Due to its affordability and applicability, bioelectrical impedance analysis (BIA), a hydrometric, non-invasive, repeatable and safe method,[21] is widely used in China to calculate fat and muscle mass to assess body composition.[22]

The pregnancy period lasts ~280 days (or 40 weeks). In terms of clinical picture, pregnancy is divided into the following three stages: early pregnancy, beginning at <14 weeks; midterm pregnancy, which lasts between 14 and 27 weeks; and late pregnancy, which begins at 28 weeks.[23 24] Currently, an oral glucose tolerance test is commonly used to diagnose GDM in the middle and late stages of pregnancy.[25] Abnormal BFP caused by an unhealthy lifestyle can be currently treated. If the significance of abnormal BFP in the development of GDM can be established, the patient can undergo early intervention to avoid unfavourable pregnancy outcomes. Therefore, the present study aimed to determine whether BMI and BFP could be used to predict pregnancy outcomes in patients with GDM.

METHODS

Study design

In the current study, the data of pregnant women who delivered at the Wenzhou Medical University Affiliated Second Hospital (Zhejiang Province, China) were analysed. All participants provided written informed consent for the use of their data.

Study population

The study population is composed of 4957 patients with GDM who gave birth at the Affiliated Second Hospital of Wenzhou Medical University between January 2019 and December 2021. Finally, a total of 683 pregnant women were included in the study (online supplemental figure 1). Subsequently, based on the description of the testing device and clinical findings, the study population was divided into two groups according to a BFP cut-off value of 33% (online supplemental explanation).[26] The inclusion criteria were as follows: (1) Pregnant women diagnosed with GDM. Therefore, women with at least one value of elevated glucose based on the International Association of Diabetes in Pregnancy Study Group criteria (fasting ≥5.1 mmol/L, 1 hour ≥10.0 mmol/L, or 2 hours ≥8.5 mmol/L)[17] were diagnosed with GDM; (2) pregnant women with GDM who have well-controlled blood glucose levels (fasting blood glucose levels should be controlled between 3.3 and 5.3 mmol/L, while the blood glucose levels at 2 hours after a meal should be controlled between 4.4 and 6.7 mmol/L) through exercise and diet control; (3) pregnant women who regularly underwent prenatal examinations at the Affiliated Second Hospital of Wenzhou Medical University, with complete medical records and data. The exclusion criteria were as follows: (1) Patients with pre-existing diabetes, essential hypertension, hyperthyroidism, hypothyroidism or malignancy prior to pregnancy; (2) patients with a history of severe genetic defects and mental illness; (3) patients with ultrasonographic evidence of congenital fetal abnormalities; (4) patients on insulin; and (5) patients with poor glycaemic control. The delivery results were followed up.

Measurements

At the time of diagnosis of GDM, BMI and BFP values were collected. Body composition was measured during fasting and after urination using the body composition analyser (Inbody770, Korea), according to the manufacturer's recommendations. BMI prior to pregnancy (Pre-BMI) was calculated using weight in kg 3 months prior to pregnancy, which was self-reported by the participants, divided by the square of the patient's height in metres (kg/m^2).[27] BMI at the time of diagnosis of GDM was the maternal BMI. Pregnancy outcomes were based on clinical conditions, such as premature birth, caesarean section, postpartum haemorrhage and stillbirth.

Statistical analysis

Statistical analyses were performed using Social Package for Social Sciences (SPSS) for Windows (V.22.0; SPSS) and SPSSAU (https://spssau.com/). All data are expressed as mean±SD or frequency (%). Continuous variables were compared using analysis of variance, while categorical ones with the χ^2 test. The crude and adjusted OR and 95% CIs were calculated by univariate and multivariate logistic regression analysis, respectively. Maternal BMI and classified BFP were independent predictors of pregnancy outcomes that were entered into the model, and age, pregnancy period (at diagnosis of GDM) and weight gain were adjusted. The receiver-operating characteristic (ROC) curves were constructed to calculate the area under the curve (AUC) of different measures of maternal BMI and BFP in predicting pregnancy outcomes.

Post hoc power analysis using G*Power (V.3.1.9.7.) was performed to evaluate whether the results had sufficient verification power. Only the results with statistical

Table 1 Demographic characteristics of the study population

	BFP <33% (n=289)	BFP ≥33% (n=394)	P value
Age (years)	31 (7)	31 (7)	0.657
Duration of gestation (at diagnosis of GDM, weeks)	26 (3)	27 (4)	**0.017**
Follow-up time (weeks)	13 (4)	12 (5)	**0.001**
Pre-BMI (kg/m^2)	20.44 (2.69)	23.31 (3.33)	**0.000**
Maternal BMI (kg/m^2)	23.15 (2.49)	26.39 (3.23)	**0.000**
BMI growth (kg/m^2)	2.71 (1.86)	3.08 (1.78)	**0.009**
Clinical symptoms			
Amniotic fluid volume			**0.008**
Normal (n (%))	283 (97.92)	369 (93.65)	
Oligohydramnios (n (%))	5 (1.73)	24 (6.09)	
Hydramnios (n (%))	1 (0.34)	1 (0.25)	
Blood pressure			**0.022**
Normal (n (%))	274 (94.81)	354 (89.85)	
Gestation hypertension (n (%))	7 (2.42)	21 (5.33)	
Mild pre-eclampsia (n (%))	6 (2.08)	15 (3.81)	
Severe pre-eclampsia (n (%))	2 (0.69)	4 (1.02)	
Anaemia			**0.002**
Normal (n (%))	247 (85.47)	301 (76.40)	
Mild anaemia (n (%))	27 (9.34)	51 (12.94)	
Moderate anaemia (n (%))	15 (5.19)	42 (10.66)	

Values are presented as mean±SD, median (IQR) or number of patients (%). The bold values represent a p value <0.05, BFP <33% group versus BFP ≥33% group.
BFP, body muscularity percentage; BMI, body mass index; GDM, gestational diabetes mellitus .

power over sufficient limits (80%) were statistically effective (online supplemental table 1). Wilks' lambda test has been used to evaluate the effectiveness of regression models (online supplemental table 2). Delong's test has been used to compare ROC curves (online supplemental table 3). P value <0.05 was considered to indicate a statistically significant difference.

RESULTS

Demographic and clinical characteristics of the study population

Among the 683 pregnant women, 289 exhibited a BFP <33% and 394 a BFP ≥33%. Statistically significant differences were obtained between the two groups in terms of duration of gestation, follow-up time, pre-BMI, BMI growth and clinical symptoms, including abnormal amniotic fluid volume (p<0.05), gestational hypertension (p<0.05) and anaemia (p<0.05; table 1).

Pregnancy outcome of the study population

The incidence of the occurrence of postpartum haemorrhage and the proportion of full-term caesarean deliveries in the BFP ≥33% group were significantly higher than those in the BFP <33% group (p<0.05; table 2). In terms of newborn weight, the incidence of macrosomia increased in the group with BFP ≥33% (p<0.05; table 2). Simultaneously, factors related to spontaneous delivery and caesarean section were analysed (table 3). It was found that the factors affecting caesarean section in preterm and term labour were increased when BFP ≥33% (p<0.05).

Maternal BMI and classified BFP can predict adverse pregnancy complications and outcomes

After adjusting confounding factors such as age, pregnancy period (at diagnosis of GDM) and weight gain, logistic regression analyses revealed that maternal BMI was an independent risk factor for predicting abnormal blood pressure, anaemia, caesarean section and macrosomia, while classified BFP was an independent risk factor for abnormal amniotic fluid volume, abnormal blood pressure, anaemia and caesarean section (table 4, online supplemental table 2). After comparing the ROC curves, it was found that the combination of maternal BMI and classification BFP had statistical significance compared with single classified BFP in terms of abnormal blood pressure and caesarean section (table 5, online supplemental figure 2 and table 3).

DISCUSSION

In the present study, two significant findings emerged regarding the association between BMI and BFP,

Table 2 Pregnancy outcome of the study population

	BFP <33% (n=289)	BFP ≥33% (n=394)	P value
Labour*			0.781
Preterm labour†			0.200
Spontaneous delivery (n (%))	14 (4.84)	12 (3.04)	
Caesarean section (n (%))	18 (6.23)	29 (7.36)	
Term labour†			**0.001**
Spontaneous delivery (n (%))	172 (59.52)	189 (47.97)	
Caesarean section (n (%))	85 (29.41)	164 (41.62)	
Postpartum haemorrhage (mL)	200(200)	300 (162.5)	**0.000**
Birth weight (g)	3200.39 (443.68)	3265.28 (492.95)	0.079
Macrosomia (n (%))	5 (1.73)	21 (5.33)	**0.015**

Values are presented as mean±SD, median (IQR) or number of patients (%). The bold values represent a p value <0.05.
*BFP <33% group versus BFP ≥33% group, comparison of the difference in the proportion of preterm labour and term labour.
†BFP <33% group versus BFP ≥33% group, comparison of the difference in the proportion of spontaneous delivery and Caesarean section.
BFP, body fat percentage.

measured in the middle and late stages of pregnancy, and pregnancy outcomes. First, the results revealed significant differences between the BFP <33% and BFP ≥33% groups. Therefore, pregnant women in the BFP ≥33% group were more prone to experience abnormal amniotic fluid volume, abnormal blood pressure, anaemia, postpartum haemorrhage and macrosomia, as well as risk factors associated with caesarean section at delivery. Second, combination of maternal BMI and classification BFP had statistical significance compared with single classified

Table 3 The factors of normal delivery and caesarean section

	BFP <33% (n=289)		BFP ≥33% (n=394)	
	Preterm labour	Term labour	Preterm labour	Term labour
Spontaneous delivery				
Normal (n (%))	1 (0.35)	36 (12.56)	4 (1.02)	27 (6.85)
Forceps delivery (n (%))	0	5 (1.73)	1 (0.25)	8 (2.03)
First degree tear (n (%))	9 (3.11)	53 (18.34)	2 (0.51)	76 (19.29)
Second degree tear (n (%))	3 (1.04)	78 (26.99)	5 (1.27)	78 (19.80)
Caesarean section*†				
Malpresentation (n (%))	0	13 (4.50)	7 (1.78)	17 (4.31)
Scarred uterus (n (%))	4 (1.38)	36 (12.56)	8 (2.03)	63 (15.99)
Placenta previa (n (%))	0	2 (0.69)	2 (0.51)	3 (0.76)
Macrosomia (n (%))	0	8 (2.77)	0	35 (8.88)
Intrauterine asphyxia (n (%))	4 (1.38)	10 (3.46)	3 (0.76)	12 (3.05)
Eclampsia (n (%))	3 (1.04)	2 (0.69)	3 (0.76)	6 (1.52)
Twins (n (%))	6 (2.08)	1 (0.35)	6 (1.52)	3 (0.76)
Elderly parturient woman (n (%))	0	2 (0.69)	0	4 (1.02)
Oligohydramnios (n (%))	0	2 (0.69)	0	3 (0.76)
Protracted second stage (n (%))	0	0	0	1 (0.25)
Cord around neck (n (%))	0	0	0	1 (0.25)
Patient's requirement (n (%))	1 (0.35)	6 (2.08)	0	10 (2.54)
Paroxysmal disease (n (%))	0	3 (1.04)	0	6 (1.52)

Values were presented as the number of patients (%).
*p<0.05, BFP <33% group versus BFP ≥33% group, comparison of factors related to caesarean section in preterm labour.
†p<0.05, BFP <33% group versus BFP ≥33% group, comparison of factors related to caesarean section in term labour.
BFP, body fat percentage.

Table 4 Association between maternal BMI and classified BFP with adverse pregnancy of the study population

		Maternal BMI			Classified BFP		
		OR	95% CI	P value	OR	95% CI	P value
Abnormal amniotic fluid volume	Univariate	1.037	0.950 to 1.153	0.524	3.184	1.302 to 7.865	**0.022**
	Model	1.044	0.942 to 1.157	0.441	3.196	1.294 to 7.894	**0.012**
Abnormal blood pressure	Univariate	1.166	1.091 to 1.263	**0.000**	2.306	1.190 to 4.524	**0.021**
	Model	1.170	1.090 to 1.275	**0.000**	2.321	1.186 to 4.545	**0.014**
Anaemia	Univariate	1.062	1.016 to 1.130	**0.019**	1.799	1.223 to 2.720	**0.008**
	Model	1.073	1.016 to 1.134	**0.011**	1.817	1.216 to 2.714	**0.004**
Preterm labour	Univariate	1.043	0.996 to 1.118	0.205	0.946	0.570 to 1.516	0.811
	Model	1.051	0.981 to 1.127	0.159	0.933	0.572 to 1.522	0.781
Caesarean section	Univariate	1.145	1.102 to 1.205	**0.000**	1.727	1.273 to 2.356	**0.001**
	Model	1.150	1.096 to 1.208	**0.000**	1.734	1.270 to 2.367	**0.001**
Postpartum haemorrhoea	Univariate	1.063	0.932 to 1.166	0.281	1.567	0.732 to 3.383	0.271
	Model	1.059	0.957 to 1.172	0.264	1.571	0.728 to 3.389	0.250
Macrosomia	Univariate	1.162	1.071 to 1.288	**0.002**	1.733	0.796 to 3.877	0.174
	Model	1.169	1.063 to 1.285	**0.001**	1.752	0.790 to 3.883	0.168

Model was adjusted for age, pregnancy period (at diagnosis of GDM) and weight gain. The bold values represent a p value <0.05.
BFP, body fat percentage; BMI, body mass index; GDM, gestational diabetes mellitus .

BFP in terms of abnormal blood pressure and caesarean section.

Although there is a definite association between BFP and BMI,[28] previous studies revealed that Chinese inhabitants, like other Asian ethnicities, exhibited lower BMI but greater BFP compared with gender-matched and age-matched Caucasians.[29 30] In addition, Gómez-Ambrosi *et al* demonstrated that women with normal BMI, suffering from pre-diabetes or type 2 diabetes, had increased BFP.[31] When the association between BMI and body fat was insufficient, such as in cases of high muscle mass, significant fluid retention and recessive obesity (low BMI with high BFP),[32] prenatal screening of BFP could provide clinicians with new information on GDM risk assessment.

Currently, GDM incidence has reached 18.9% in China, and it is significantly associated with prenatal obesity.[25 33] In this study, the pre-BMI mean values in the BFP <33% and BFP ≥33% groups were within normal ranges, thus suggesting that GDM risk could not be fully represented by BMI alone. The increase in body fat and fat free weight during pregnancy are the key factors associated with pregnancy outcomes in women with normal prepregnancy weight.[34] Continued weight gain during the middle and late stages of pregnancy can lead to the accumulation of

Table 5 Area under ROC curve

		AUC	95% CI	P value
Maternal BMI	Abnormal blood pressure	0.664	0.578 to 0.750	0.000
	Anaemia	0.569	0.516 to 0.623	0.012
	Caesarean section	0.630	0.588 to 0.672	0.000
	Macrosomia	0.636	0.524 to 0.747	0.012
Classified BFP	Abnormal amniotic fluid volume	0.620	0.528 to 0.712	0.024
	Abnormal blood pressure	0.593	0.514 to 0.672	0.031
	Anaemia	0.570	0.517 to 0.623	0.012
	Caesarean section	0.566	0.523 to 0.610	0.003
Maternal BMI and classified BFP	Abnormal amniotic fluid volume	0.628	0.545 to 0.711	0.016
	Abnormal blood pressure	0.666	0.583 to 0.749	0.000
	Anaemia	0.583	0.531 to 0.635	0.003
	Caesarean section	0.631	0.589 to 0.673	0.000
	Macrosomia	0.637	0.525 to 0.748	0.012

AUC, area under the curve; BFP, body fat percentage; BMI, body mass index; ROC, receiver-operating characteristic.

fat in the vulvar and pelvic wall, thus negatively affecting labour progression via promoting or even interrupting it, as well as via increasing the likelihood of a caesarean section.[33] Consistent with previous studies, here, pregnant women with higher BFP also displayed a higher possibility of caesarean section.

The prevalence rate of macrosomia in several parts of China ranges between 3.1% and 7.8%.[35 36] The Pedersen hypothesis suggested that the enhanced levels of maternal glucose could stimulate fetal insulin synthesis, thus promoting fetal growth and obesity.[37] Other studies indicated that fetal insulin production could be affected by factors other than maternal glucose levels, including amino acids, lipids, and the secretion of adipokine hormones by the mother's fat, eventually resulting in macrosomia.[38–41] Additionally, a previous study revealed that the maternal lipid profile was an independent risk factor for fetal overgrowth during pregnancy.[42] The results of the present study suggested that although the classified BFP could not be used to predict macrosomia, patients in the high BFP group displayed a significantly greater incidence of macrosomia.

Obesity during pregnancy is associated with a range of adverse consequences, and BMI is a commonly used indicator for predicting obesity.[43] An individual patient meta-analysis from 39 cohort studies undertaken in Europe, Australia and North America estimated that 23.9% of all pregnancy complications can be attributed to maternal overweight or obesity prior to pregnancy, and mothers with a BMI ≥40 have the highest risk of developing pregnancy complications.[44] Furthermore, children born to women who were obese during pregnancy also had a higher risk of obesity.[45] The results of the current study further verified the significance of BMI in predicting adverse pregnancy outcomes. Therefore, the combination of BMI and classified BFP could improve the prediction rate. If active and scientific intervention measures are considered to carefully monitor and control body fat after the diagnosis of diabetes during the second trimester of pregnancy, weight gain during pregnancy could be more effectively managed.

However, the current study has several limitations. First, since the present retrospective study was carried out in a single location, further prospective cohort studies are needed to verify the results of this study. Second, BIA provides an inexpensive, faster and less invasive option, but the effectiveness of BIA instruments varies by manufacturer.[46] Furthermore, other data, such as insulin levels, blood cholesterol levels or visceral fat,[47] were not considered in this study, and only the effect of BMI and BFP on pregnancy outcomes in the middle and late stages of pregnancy was evaluated.

CONCLUSIONS

In summary, the current retrospective study indicated that patients with GDM and BFP ≥33% were more prone to unfavourable pregnancy outcomes, caesarean section and macrosomia. The above findings suggested that the combination of BMI and classified BFP could more effectively predict pregnancy outcomes of patients with GDM during the middle and late stages of pregnancy.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the ethics committee of the Wenzhou Medical University Affiliated Second Hospital (approval no. 2022-k-234-02). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data used to support the findings of this study are available from the corresponding author on request.

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