

The combination of symphysis-fundal height and abdominal circumference as a novel predictor of macrosomia in GDM and normal pregnancy

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Abstract

Background Macrosomia is a major adverse pregnancy outcome of gestational diabetes mellitus (GDM). Although BMI, symphysis-fundal height (SFH) and abdominal circumference (AC) are associated with fetal weight, there are some limitations to their use, especially for the prediction of macrosomia. This study aimed to identify a novel predictive methodology to improve the prediction of high-risk macrosomia.

Methods Clinical information was collected from 3730 patients. The association between the ISFHAC (the index of SFH algorithm multiplied by the square of AC) and fetal weight was performed and validated. A new index, the ISFHAC, was evaluated by area under the curve (AUC) analysis.

Results A total of 1087 GDM and 657 normal singleton pregnancies were analyzed. ISFHAC was positively correlated with fetal weight in GDM pregnancies and normal pregnancies (NPs). The AUCs of the ISFHAC were 0.815 in the GDM group and 0.804 in the NP group, which were higher than BMI, SFH, AC and GA. The ISFHAC cutoff points were 41.7 and 37 in the GDM and NP groups, respectively. The sensitivity values for the prediction of macrosomia with high ISFHAC were 75.9% and 81.3% in the GDM and NP groups, respectively, which were higher than that for the prediction of BMI. Regarding the validation data, the sensitivity values for prediction with a high ISFHAC were 78.9% (559 GDM pregnancies) and 78.3% (1427 NPs).

Conclusions The ISFHAC can be regarded as a new predictor and risk factor for macrosomia in GDM pregnancy and NP.

Introduction

The increasing prevalence of overweight/obesity during pregnancy has increased the risk of adverse pregnancy outcomes by increasing the prevalence of GDM. Gestational diabetes mellitus (GDM) is defined as glucose intolerance that is first diagnosed during pregnancy [1]. Women with GDM have high levels of blood glucose and Insulin like growth factor (IGF). In the relatively long period of pregnancy, fetuses are in a state of rapid growth with high levels of nourishment, especially in middle and late pregnancy. Nutritional counseling and exercise intervention are suitable noninvasive therapeutic options that can be readily applied to manage weight gain and improve the pregnancy outcomes of women with GDM [2-6]. The incidence of fetal macrosomia and cesarean delivery is also significantly higher for GDM pregnancies [7]. Fetal macrosomia, defined as a birth weight $\geq 4,000$ g, affects 12% of newborns from non-GDM pregnancies and 15-45% of newborns from GDM pregnancies [8-9]. Thus, in the context of GDM, fetal growth assessment is an important part of antenatal care. BMI, obesity and waist circumference are the conventional risk factors for pregnancy outcomes. B-ultrasonography, the symphysis-fundal height (SFH) chart and abdominal circumference (AC) measurements are monitoring approaches that are used routinely in departments of obstetrics and gynecology. Several studies have revealed that BMI, obesity, SFH and AC are associated with fetal weight, and these parameters are commonly used to predict fetal size and select a safe delivery method [10-12]. However, BMI, SFH and AC are not powerful enough for the diagnosis of macrosomia [13]. The aim of this study was to develop a new index to predict macrosomia. The index of symphysis-fundal height and abdominal circumference (ISFHAC) combines SFH and AC, which are used to evaluate fetal birth weight, and this index has great potential for use in predicting macrosomia in normal pregnancies (NPs) and GDM pregnancies.

Materials And Methods

Study design

The prospective study was conducted from 2013–2016 at the Department of Obstetrics and Gynecology in Zhongnan Hospital of Wuhan University. All participants provided informed written consent prior to taking part. This process, together with all other aspects of the study, was approved by the Research Ethics Committee of Wuhan University.

The method and procedure of this study was designed and the inclusion and exclusion criteria were performed. Pregnant women included ≥ 16 years and a singleton pregnancy were recruited. All patients received standard prenatal checkups between 24 and 28 weeks. Study group was divided into GDM and NP by OGTT. If a patient develops GDM, the intervention began, such as physical activity and dietary behavioral intervention [14]. To improve the accuracy of these parameters, repeated measurement was performed by averaging the testing values. In addition, the patients were divided into two sets. One set comprised 1744 patients was used to analyze the relationship between several clinical parameters (abdominal circumference, symphysis-fundal height BMI and gestational age) and macrosomia in NP group and GDM group, The other set comprised 1986 patients was used to validate the results (Fig. 1).

Participants

All participants were enrolled according to the diagnostic criteria for GDM of WHO 2013 [15]. All pregnant women received a 75-g OGTT between 24 and 28 weeks. Two types of participants were excluded: one type is hypertensive disorder of pregnancy and other diseases (e.g. assisted fertilization), the other is pregestational diabetes mellitus.

Procedures

Data on characteristics including past medical history included hypertension, pregestational diabetes mellitus and preeclampsia *etc.*, family history of DM and information before delivery, such as gestational age (GA), age, parity, prepartum height and weight, mode of delivery. SFH, AC, and fetal birth weight were collected for each study group. The validation set was mainly missing prepartum BMI data, but the other clinical data were sufficient.

BMI calculations are routinely performed before childbirth in patients who appear underweight, overweight or obese.

Gestational age was based on reliable, regular last normal menstrual period confirmed by ultrasound fetal biometry <20 weeks or ultrasound dating performed at <20 weeks. GA was major clinical parameter which was identified by doctor from the information of pregnant woman.

Infant weight was measured by an obstetrician or midwife after delivery. Weight assessment was measured by baby scales, and got nude weight data. These data were account to two decimal places. The criterion for macrosomia is that whose birth weight $\geq 4,000$ g.

SFH was measured from the superior border symphysis to the highest uterine fundus. The tape was positioned with one hand over the upper border of the symphysis pubis bone, the tape was placed in a straight line over the uterus until loss of resistance was felt when reaching the fundus. The tape was turned so that the numbers were visible to record the value to the nearest complete one centimeter. SFH was measured by doctor at the prenatal check-up. The last SFH measurement was at ante partum.

AC was defined as the length of abdominal circumference through the umbilicus. Data was determined by the measurement of abdomen circumference with measuring tape.

We assumed that a pregnant woman's abdomen was cylindrical, if delivery women' abdomen is an ideal cylinder, we know that volume is equal to basal area times that height. According to the density calculation formula, we could obtain the weight. This parameter was served as a new index that predicted fetal weight. New index was calculated with the formula below: $ISFHAC \times SFH (m) \times AC (m)^2 \cdot \rho$ in the formula is the density of human body. in the formula would be taken as a constant, which approximately equaled 100. Thus, ISFHAC was performed to predict for macrosomia.

First, logistic regression was used to analyze the relationship between macrosomia and the data parameters. Then, ROC curve analysis was carried out with the ISFHAC and macrosomia. We determined the cutoff points for NP and GDM pregnancy. According to the following cut-off point, samples were dividing into high and low index group: less than cut-off points as the low index group, greater than cut-off point as the high index group in GDM and NP group. To verify the predictive of the ISFHAC for macrosomia, the ISFHAC was applied in the analysis set (1744) and the validation set (1986).

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics version 20.0. For measurement data, an independent-sample t-test was used. Afterward, ROC curve analysis was performed with the ISFHAC and macrosomia. We determined the capacity of ISFHAC for predicting macrosomia by Univariate Logistic Regression Analysis. To compare the effect of the predictive value of BMI for macrosomia, we examined the effect of its prediction of macrosomia in the NP and GDM groups in the analysis cohort. Sensitivity, specificity and accuracy were determined in the analysis.

Validation of the prediction model

To further evaluate the predictive effect of the ISFHAC for macrosomia, data from another 1986 additional patients were used for the clinical trial evaluation. Sensitivity, specificity and accuracy were estimated.

Results

Study characteristics

According to the data we collected, the ages of the participants ranged from 16 to 54, and women with GDM were older than women in the control group. The mean prenatal BMI in the GDM group was higher than that in the control group. Obesity in the GDM group was 3.27-fold that in the control group, while the number of patients with normal weight in the control group was 2.53-fold that in the GDM group. There were statistically significant differences in BMI categories between the control and GDM groups. The ratio of multiparas with GDM was 2.17-fold that of multiparas in the NP group, and the family history of DM was higher in the GDM group than in the control group. The percentage of cesarean sections was 75.6% in the GDM group, which was higher than that in the control group (69.9%) (Table1).

TABLE 1 Characteristics of NP and GDM pregnancy groups.

| | NP (N=657) | GDM (N=1087) | P-value |
|------------------------------------|--------------|--------------|-----------------------|
| Mean (SD) age at delivery (y) | 28.86 (3.96) | 29.62 (4.76) | P=0.001 ^a |
| Mean (SD) gestational weeks (w) | 38.81 (1.80) | 38.91 (1.22) | P=0.175 ^a |
| Women with BMI | | | |
| Mean (SD) BMI (kg/m ²) | 26.36 (3.04) | 29.1 (3.95) | P<0.0001 ^a |
| Pregnancy BMI categories (%) | | | P<0.0001 ^b |
| ≥ 18.5 & < 25 | 213 (32.4%) | 139 (12.8%) | |
| ≥ 25 & < 30 | 358 (56%) | 536 (49.3%) | |
| ≥ 30 | 76 (11.6%) | 412 (37.9%) | |
| Parity (%) | | | P<0.0001 ^b |
| Nulliparous | 535 (81.4%) | 649 (59.7%) | |
| Parous | 122 (18.6%) | 438 (40.3%) | |
| Family history (%) | | | P<0.0001 ^b |
| No DM | 646 (98.3%) | 954 (87.8%) | |
| With DM | 11 (1.7%) | 133 (12.2%) | |
| Mode of delivery (%) | | | P=0.009 ^b |
| Vaginal | 195 (30.1%) | 266 (24.4%) | |
| Cesarean section | 453 (69.9%) | 824 (75.6%) | |

GDM, gestational diabetes mellitus; BMI, body mass index. Regarding pregnancy BMI categories, ≥ 18.5 & < 25 means normal weight; ≥ 25 & < 30 means overweight; ≥ 30 means obesity. Regarding gestational weeks, < 37 means premature birth; ≥ 37 & < 42 means mature birth; ≥ 42 means postterm birth. ^a p values were calculated using the independent sample T-test, and ^b p values were calculated using the chi-square test.

ISFHAC is a novel potential predictor for macrosomia

As was shown in supplementary Table 1, the logistic regression analysis indicated that fetal weight was associated with SFH, AC and BMI. Subsequently, in order to evaluate the effect of the ISFHAC in predicting the risk of macrosomia, ROC curve analysis was performed on the data for analysis and evaluation (Fig. 2). The area under the curve (AUC) of the ISFHAC was larger (area = 0.803, $p < 0.0001$) in the control group, and the AUC of the ISFHAC was larger (area = 0.815, $p < 0.0001$) in GDM which were higher than BMI, SFH, AC and GA. The prediction ability of ISFHAC is higher than other parameters. Thereby, we could determine the cutoff points of each group (Table 2). The ISFHAC value was higher in the GDM group than in the control group.

The cutoff points for the ISFHAC in the NP and GDM groups were 37 and 41.7, respectively. The ISFHAC values were divided into three categories according to BMI. Of note, in the GDM and NP groups, 41.7 and 37, respectively, were the lower bounds for the ISFHAC according to obesity (Supplementary Table 2).

TABLE 2 ROC curve analysis of the utility of clinical parameters for predicting macrosomia

| | GDM | | NP | |
|--------|-------|----------------------|-------|----------------------|
| | Area | P-value ^a | Area | P-value ^a |
| ISFHAC | 0.815 | <0.001 | 0.803 | <0.001 |
| SFH | 0.804 | <0.001 | 0.767 | <0.001 |
| AC | 0.753 | <0.001 | 0.744 | <0.001 |
| BMI | 0.707 | <0.001 | 0.651 | <0.001 |
| GA | 0.540 | 0.07 | 0.640 | <0.001 |

^a p values were calculated by ROC curve analysis.

ISFHAC can predict macrosomia in GDM pregnancy and NP

Moreover, there were 208 and 64 cases of macrosomia in the GDM (1087, 19.1%) and NP (657, 9.7%) groups, respectively; the rate of macrosomia in the GDM group was 2-fold that in the NP group. Samples were divided into high- and low-ISFHAC groups according to the following cutoff points: less than 41.7 as the low index group and greater than 41.7 as the high index group in the GDM group and less than 37 as the low index group and greater than 37 as the high index group in the NP group. We further predicted macrosomia in our study. The cutoff point was 41.7 in the GDM group, with a sensitivity of 75.9%, specificity of 72.9%, and accuracy of 73.5%. The cutoff point was 37 in the NP group, with a sensitivity of 81.3%, specificity of 66.4%, and accuracy of 67.9% (Table 3). A high ISFHAC value could predict 75.9% of macrosomia cases, but with BMI, the prediction for macrosomia was only 60.1% in the GDM group. In the NP group, the high ISFHAC and BMI prediction values were 81.3% and 25%, respectively (Table 3).

TABLE 3 Macrosomia with ISFHAC and BMI analysis

| | GDM (N = 1087) | | NP (N = 657) | |
|-----------------------|--------------------|----------------|-------------------|----------------|
| | Macrosomia (n=208) | Normal (n=879) | Macrosomia (n=64) | Normal (n=593) |
| ISFHAC $\geq 41.7/37$ | 158 (75.9%) | 238 (27.1%) | 52 (81.3%) | 199 (33.6%) |
| BMI ≥ 30 | 125 (60.1%) | 287 (32.7%) | 16 (25%) | 60 (10.1%) |

Validation results

To evaluate the predictive power of the ISFHAC, 559 (GDM pregnancy) and 1427 (NP) women were screened for validation and used for the clinical trial evaluation. A high ISFHAC value could predict macrosomia in the NP group with a sensitivity of 78.9%, specificity of 71.3%, and accuracy of 72.1%. In the GDM group, the sensitivity was 78.3%, specificity was 82.8%, and accuracy was 82.3% (Table 4).

TABLE 4 The validation of ISFHAC for predicting macrosomia in the GDM pregnancy and NP groups

| | GDM (N = 559) | | NP (N = 1427) | |
|-----------------------|-------------------|----------------|--------------------|-----------------|
| | Macrosomia (n=60) | Normal (n=499) | Macrosomia (n=147) | Normal (n=1280) |
| ISFHAC $\geq 41.7/37$ | 47 (78.3%) | 86 (17.2%) | 116 (78.9%) | 367 (28.7%) |
| ISFHAC $< 41.7/37$ | 13 (21.7%) | 413 (82.8%) | 31 (21.1%) | 913 (71.3%) |

Discussion

In recent decades, China has changes in dietary intake and decreased physical activity [16]. The report released in China shows that comprising 72.1 million female patients, have prediabetes. Among women between the ages of 20 and 39 years, approximately 5.6 million have DM (3.2%) and 15 million have prediabetes (9%) [17].

Regarding the specific eating habits of Chinese people and the lack of sufficient exercise during pregnancy, obesity in the GDM group was higher than in the NP group. A previous study revealed that normal weight accounted for most NPs [18]. In this study, however, 67.6% and 87.2% of the patients in the NP and GDM groups, respectively, were overweight and obesity.

A higher BMI, AC, and fasting glucose in the first trimester of pregnancy increased GDM risk [19]. Excessive gestational weight gain, according to the targets set by the Institute of Medicine (IOM), was associated with cesarean section, LGA and macrosomia. Modification of the IOM criteria, including more restrictive targets, did not improve perinatal outcomes [20]. Our results indicated that there was a high percentage of obesity in the GDM group and was 1.96-fold that of control group for predicting macrosomia, and that obesity can also lead to adverse pregnancy outcomes. In addition, other groups have reported the relationship between obesity and adverse pregnancy outcomes [21].

In a previous study, the incidence of fetal macrosomia (the main outcome) was significantly higher in the GDM group (20.0%) than in the control group (3.6%) [22]. In our research, fetal macrosomia was observed in 9.7% of women in the control group and 19.1% of women with GDM.

SFH and AC are two routine measurements in obstetrical departments. They have clinical significance for predicting infant size and as a reflection of the pregnant woman's nutritional status for reference. These findings support the internal validation of the SFH chart, which may be implemented in the prenatal care of patients with diabetes and pregnancy [12]. But the reference shows that there is no evidence that SFH is useful to identify macrosomia [13]. The SFH measurement is primarily practiced to detect fetal intrauterine growth restriction (IUGR). Undiagnosed IUGR may lead to fetal death, as well as increased perinatal mortality and morbidity [23].

To our knowledge, this is the first time that the notion of combining SFH and AC to calculate the ISFHAC was put forth as a new indicator of pregnancy outcome.

Regarding the AUCs of different parameters, the AUC for the ISFHAC is the largest among the NP and GDM groups. Thus, we think that the relationship between the ISFHAC and macrosomia is relevant. In this study, the cutoff points for the ISFHAC are 37 and 41.7 in the control and GDM groups, respectively. Women in the high bin of the index were prone to adverse pregnancy outcomes. Interestingly, 41.7 was the lower bound of the ISFHAC, which is consisted with obesity in GDM, and 37 was the lower bound of the ISFHAC in the control group, which is also in accordance with obesity. In analysis group, our results indicated that ISFHAC is superior to other parameters (e.g. BMI) for prediction macrosomia. Thus, we only analyzed the new index in the validation group.

We were interested in the high index group. Here, the high ISFHAC predicted (75.9%) most of the macrosomia cases in the GDM group, and this rate was higher than that of the obesity-based grouping (60.1%).

In the NP group, the high ISFHAC predict 81.3% of macrosomia cases, and obesity predicted 25% of macrosomia. The high ISFHAC prediction ability for macrosomia was better than that of the obesity-based grouping.

In another validation dataset, the high ISFHAC predicted most of the macrosomia cases in the NP and GDM groups. High ISFHAC was a risk factor for macrosomia.

All measures used should aim to prevent excessive SFH and AC, and the high ISFHAC group needs exercise or dietary intervention. Chinese GDM prevention and treatment programs should target overweight and obese adults with central obesity. Pregnancy SFH and AC control is an important target to reduce the risk of an adverse perinatal outcome in a subsequent pregnancy. SFH and AC were constantly been used as a marker for the fetal weight, but they were useless to identify macrosomia [13]. The combining these two parameters (SFH, AC) may also have limitations. Adipose panniculus may reflect the SFH and AC, which would be positively associated with obesity-related adverse pregnancy outcomes. Thus, the new index has a potential to improve for our future research.

Ultrasound is not the routine examination. In addition, ultrasound measurements are routinely performed on all pregnant women at 18–22 weeks gestation as a screening tool for fetal anomalies. A simple clinical risk score may help obstetrician suspect macrosomia at the time of delivery in remote areas where antenatal care services are less than adequate [24].

There may be some limitations in this study. Although this study includes a large sample size it contains only patients from a single tertiary hospital and thus cannot represent the total population. Future studies would have to determine the effects of factors, for example, using different hospital data, selecting patients who choose different occupations from different regions.

Consequently, this study provides evidence that ISFHAC is more strongly associated with the risk of macrosomia than BMI. It is possible that the ISFHAC might be useful as a surrogate for developing adverse pregnancy outcomes, such as in predicting macrosomia. To further confirm our results, Future studies are warranted to predict fetal weight in different GA groups. We hope to provide the ISFHAC chart using the index at different GAs to predict fetal weight.

Abbreviations

ISFHAC: the index of SFH algorithm multiplied by the square of AC; GDM: Gestational diabetes mellitus; DM: Diabetes mellitus; BMI: Body mass index; OGTT: Oral glucose tolerance test; WHO: World Health Organization; AC: Abdominal circumference; SFH: Symphysis-fundal height; IUGR: intrauterine growth restriction; GA: gestational age; AUC: area under the curve.

Declarations

Ethics approval and consent to participate

Permission to use the data set was obtained and the study was approved by the Ethics Committee of Wuhan University. Only de-identified data was analyzed in this study.

Consent for publication

Not applicable

Availability of data and material

The datasets generated and analyzed during the current study are not publicly available due to the hospital policy but are available from the corresponding author on reasonable request.

Competing Interests

The authors have declared that no competing interests exist.

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Author Contributions

LW and ZGC: study design and revision of the manuscript. YTX, ZGC and HYH: data analysis and draft of the manuscript. ZGC, YTX, LLJ, XXC, RL, XLZ, CW, YLW and HYH: follow-up patient's information. All authors read and approved the final manuscript.

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Figures

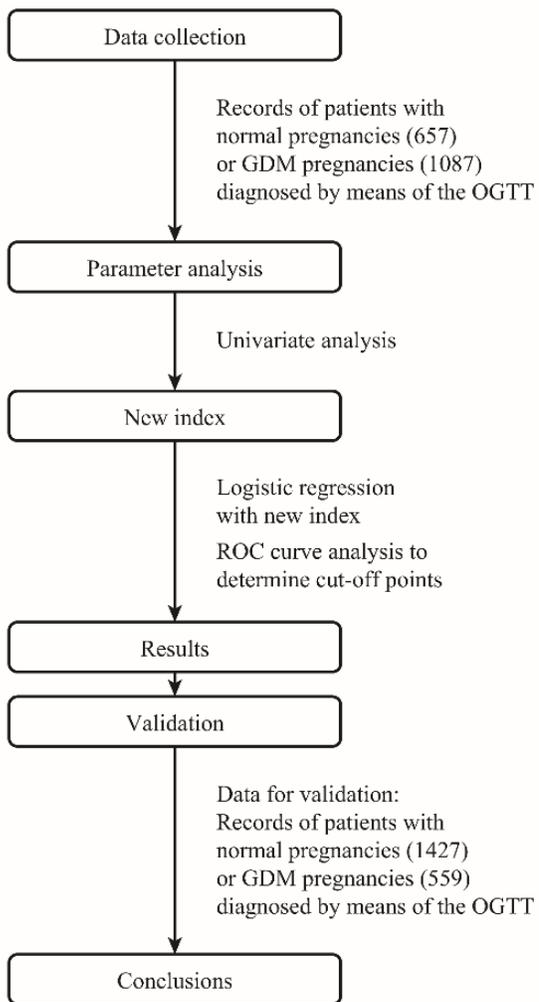


Figure 1

A total of 1744 participants (1087 GDM and 657 controls) with complete clinical data were screened for analysis.

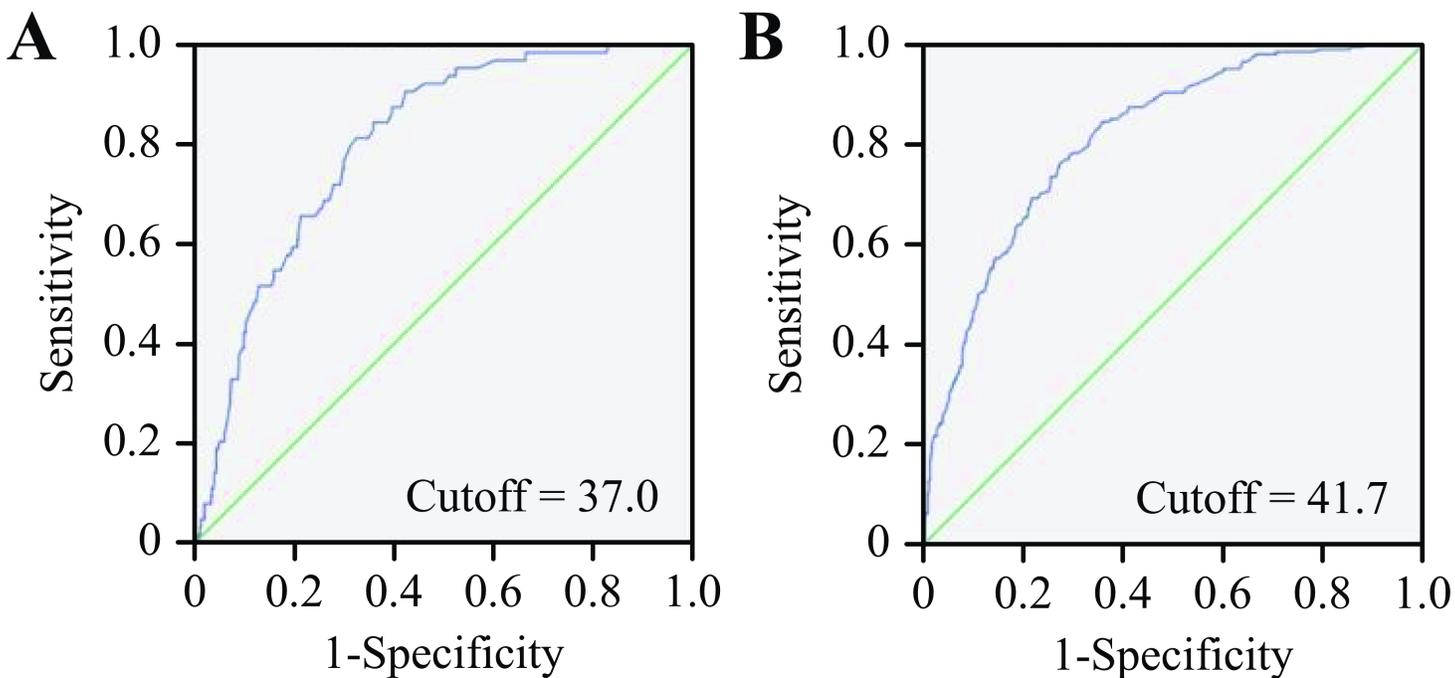


Figure 2

To evaluate the effect of the ISFHAC in predicting the risk of macrosomia, ROC curve analysis was performed on the data for analysis and evaluation. The area under the curve (AUC) of the ISFHAC was larger (area = 0.803, $p < 0.0001$) in the control group, and the AUC of the ISFHAC was larger (area = 0.815, $p < 0.0001$) in GDM.

Supplementary Files

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- [Supplementarytablewithchangesmarked.pdf](#)