Original Article

Evaluating the accuracy of sonographic fetal weight estimations using the Hadlock IV formula in a Chinese population

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Background: Despite being the most generalized formula in China, the Hadlock IV formula has never been examined to determine if it is suitable for Chinese newborns, nor have the factors that might affect its performance been investigated. However, previous studies have reported varying results about other formulas in other nationalities. This study sought to evaluate the performance of the Hadlock IV formula in estimating fetal weight (FW) in pregnant Chinese women and use ultrasound to identify the factors affecting the accuracy of estimations of newborn weight; through these means, we aimed to create a reference for predicting neonatal weight for obstetricians.

Methods: A retrospective observational study comprising data from 976 cases of live-birth singleton pregnancies at the Shanghai General Hospital was conducted. The participants' clinical data were examined and subjected to a logistic regression analysis to identify the multitude of possible factors affecting the estimation of FW. The proportions and correlations between the accurate and inaccurate estimation groups were compared to determine the different prognosis of these 2 groups. The correlations between the accuracy of the sonographic-based fetal weight estimation (SFWE) and newborns with different weight ranges were also analyzed.

Results: The overall accuracy rate of the SFWE predicted by the Hadlock IV formula was 79.61%, while that of the inaccurate estimation group was only 20.39%. The incidence of spontaneous vaginal delivery (VD) was lower in the inaccurate estimation group than in the accurate estimation group (40.7% *vs.* 48.13%; P=0.041). In the inaccurate estimation group, 11.56% (23/199) of the participants underwent a secondary cesarean section (sCS), compared to only 6.44% (50/777) in the accurate estimation group. The low birth weight (LBW) rates and macrosomia rates were lower in the accurate estimation group than in the inaccurate estimation group, with odds ratios (ORs) of 0.483 and 0.459, respectively (P<0.05). The results indicated that the SFWE was more accurate for newborns weighing 2,500–4,000 g than those weight out of this range. In relation to macrosomia, the SFWE was likely to be underestimated, but it was usually overestimated in the LBW group.

Conclusions: The overall performance of the Hadlock IV formula in predicting the birth weight of Chinese newborns remains suboptimal. Extra caution should be exercised in cases of suspected large-for-gestational age (LGA) infants, small-for-gestational age (SGA) infants, infants with macrosomia, or LBW fetuses in the Chinese population.

Keywords: Birth weight; Chinese pregnant women; estimated fetal weight (EFW); Hadlock IV; sonographic-based fetal weight estimation (SFWE)

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Introduction

Birth weight (BW) is a crucial and predictive indicator for assessing overall neonatal and maternal fitness, and can even be used to determine the management of labor and delivery. Undiagnosed or unanticipated macrosomia and a BW >4,000 g are closely correlated with increases in the incidence of prolonged labor, shoulder dystocia, birth trauma, operative vaginal delivery (VD), or secondary cesarean section (sCS) (1). Unrecognized fetal growth restriction may be related to the rise in oligoamnios, stillbirths, premature births, and neonatal asphyxia. Thus, it would be clinically useful to have a precise tool to predict newborn weight in any period of the pregnancy.

Two-dimensional ultrasound that incorporates measured parameters, such as the biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL), has been widely adopted worldwide to predict newborn weight; however, its reliability has been questioned by obstetricians. Several formulas, including those that use 3-dimensional (3D) ultrasound scans, have been developed to estimate fetal weight (FW) based on regression analyses (2-4), but these formulas have yielded inconsistent results.

The Hadlock formula is one of the oldest and most popular formulas in China. Research has shown that a number of maternal or fetal factors may affect the accuracy of sonographic-based fetal weight estimation (SFWE) (5), which is used to predict FW. An SFWE that falls within 10.0% of the neonatal birth weight is considered accurate. However, despite being the most generalized formula in China, the Hadlock IV formula has never been examined to determine if it is suitable for Chinese newborns, nor have the factors that might affect its performance been investigated.

The present study sought to assess the accuracy of the Hadlock IV formula in calculating the estimated fetal weight (EFW) of Chinese newborns. It also examined whether certain factors play a role in predicting FW to provide some appropriate solutions to avoid or reduce any inaccuracies in the EFW. We present the following article in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-22-778/rc).

Methods

Study population

This retrospective study used the data of 976 cases of singleton pregnancies from women aged 18–49 years who were hospitalized for delivery from January 2021 to December 2021 at the Department of Obstetrics, Shanghai General Hospital. The Ethics Committee of the Shanghai General Hospital approved this study. Informed consent was not required due to the retrospective nature of the study design. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

To be eligible for inclusion in this study, the patients had to meet the following inclusion criteria: (I) have had a live-birth singleton pregnancy; (II) be ≥18 years old; (III) have a fetus with a BW >1,000 g; (IV) have a time interval between the performance of the ultrasound examination and the day of birth of ≤7 days; and (V) have a fetus with a gestational age (GA) at delivery ≥28 weeks. Patients were excluded from this study if their pregnancy was complicated by a stillbirth or a fetal congenital malformation or if they had incomplete medical records.

At our hospital, all pregnant women who are expected to shortly give birth undergo a routine ultrasound scan to determine the optimal delivery method. To avoid selection bias, we collected the data of all the pregnant women who met the above-mentioned inclusion criteria. Among the 1,000 women who met the inclusion criteria, 15 patients had inadequate information, 6 refused to cooperate when they were asked a few related questions, and 3 cases were complicated by the congenital malformation of the fetus. Ultimately, 976 pregnant women were included in the analysis.

Clinical measurements

The machine used for ultrasound was a Voluson E8 (GE Healthcare, Bloomfield, USA). The following Hadlock IV formula was used: Log10 BW = 1.326 – (0.00326 × AC × FL) + (0.0107 × HC) + (0.0438 × AC) + (0.158 × FL). All the ultrasound scans were performed by experienced radiologists using standard protocols. The GA was determined using the last menstrual period (LMP) based on criteria recommended by the American College of Obstetricians and Gynecologists, and the GA was adjusted if there was a discrepancy of ≥7 days in the calculation of the GA between the LMP and crown-lump length (6).

Polyhydramnios was defined as amniotic fluid index (AFI) value ≥25 cm. Oligohydramnios was defined as an AFI value ≤5 cm. The AFI value was determined with a fourth quadrant evaluation. Body mass index (BMI) (kg/m^2) was calculated as follows: weight (kg)/height^2 (m^2). BW was measured by a midwife within 10 mins of the birth. The large-for-gestational age (LGA) is defined as a BW greater than the 90th percentile for their GA (i.e., infants that weighed 90% more than those of the same GA). Similarly, the small-for-gestational age (SGA) is defined as a BW <the 10th percentile for their GA. The appropriate-for-gestational age (AGA) is defined a BW in the 10th–90th percentiles of the average weights for their GA. A low birth weight (LBW) was defined as a newborn that weighed ≤2,500 g at birth.

Fetal presentation refers to the part of the baby that overlays the maternal pelvis. The 4 delivery methods were classified as follows: (I) VD; (II) primary cesarean section (pCS); (III) sCS; and (IV) assisted vaginal delivery (AVD), which mainly consisted of forceps-assisted deliveries.

Placenta previa occurs when the placenta partly or completely covers the cervix, which is the opening of the uterus. Uterine scarring refers to a histologically altered section of the uterine wall that forms after damage during surgical and diagnostic interventions, including previous cesarean deliveries or the excision of intramural hysteromyoma, or injuries.

The accuracy of the SFWE was analyzed using the following formula: percentage error (PE) = (SFWE – BW)/BW × 100; however, for the statistical analysis, the absolute percentage error (APE) was adopted in our research. The APE was calculated as follows: APE = (SFWE – BW)/BW × 100. The mean APE (MAPE) was defined as the average APE. If the APE fell within the 10.0% range, the SFWE was considered accurate, and the patient was assigned to the accurate estimation group; otherwise, the SFWE was considered inaccurate, and the patient was assigned to the inaccurate estimation group. The patients were also compared to investigate the parameters that determine the factors associated with SFWE inaccuracy. If the SFWE – BW was >0, it was classified as an "overestimation", and if the SFWE-BW was <0, it was classified as an "underestimation".

Statistical analyses

In relation to the descriptive statistics, the normally distributed continuous variables are presented as the mean and standard deviation, and the normally distributed categorical variables are presented as the number and percentage. No missing values were observed in any of the participants who were ultimately included in the study. The chi-squared test was used to compare the proportions and correlations. The independent samples *t*-test was used to compare and analyze the continuous numerical variables. The odds ratio (OR) and the 95% confidence interval (CI) for the accuracy of the SFWE were estimated using multivariable logistic regression models across the maternal parameters [i.e., GA, maternal pre-BMI, delivery BMI, maternal age, maternal height, gravidity, parity, gestational diabetes mellitus (GDM), gestational hypertensive disorders, *in vitro* fertilization (IVF), placenta previa, and scarred uterus], ultrasound parameters (i.e., gender, BPD, HC, AC, FL, estimation of BW, hydramnios, and oligoamnios), and fetal parameters (i.e., fetal presentation, LGA, SGA, AGA, macrosomia, and LBW). To assess the independent predictors with adjusted ORs, the variables in the univariate analysis with P values <0.05 were included in a stepwise and backward multivariable logistic regression model. A P value <0.05 was considered statistically significant.

Results

Participant characteristics.

In total, 976 patients were enrolled in the study and classified into the following 2 groups based on the accuracy of the EFW: (I) the accurate estimation group (comprising 777 patients) and (II) the inaccurate estimation group (comprising 199 patients). The main clinical characteristics of the study population are shown in *Table 1*. No significant difference was found between the 2 groups in relation to most of the indexes.

Table 1 Participant characteristics (accurate and inaccurate estimation groups)

Characteristic	Accurate estimation group (n=777, 79.61%)	Inaccurate estimation group (n=199, 20.39%)	P
Age (years)	31.57±4.50	30.87±4.00	0.044*
Height (cm)	160.25±5.08	160.13±5.50	0.765
Weight (kg)	57.65±9.43	56.27±10.63	0.072
BMI (prepregnancy)	22.43±3.52	22.11±3.53	0.252
BMI (delivery)	27.57±3.47	27.27±3.59	0.271
Gravidity	2.34±1.35	2.21±1.28	0.216
Nulliparous/multiparous	407/370	119/80	0.040*
Ultrasound parameters			
BPD	93.96±5.14	94.09±4.83	0.754
HC	330.88±12.44	329.64±16.02	0.310
AC	340.64±19.69	339.39±24.44	0.502
FL	71.77±3.25	71.48±4.29	0.371
EBW (g)	3,296.34±434.23	3,277.48±39.10	0.606
BW (g)	3,279.42±437.71	3,209.85±565.59	0.107
MAPE	4.217±2.66	13.65±3.44	0.000*
MAD	137.22±87.70	435.20±122.9	0.000*
Overestimation of BW	438 (56.4)	120 (60.3)	0.435
Ultrasound interval	4.14	4.28	0.567
GA (weeks)	38.49±1.336	38.44±1.88	0.701
Weight for GA			
LGA (n/p)	124 (15.96)	35 (17.59)	0.579
SGA (n/p)	39 (5.02)	21 (10.55)	0.004*
AGA (n/p)	614 (79.02)	143 (71.86)	0.031*
Macrosomia (n/p)	34 (4.38)	16 (8.04)	0.036*
Low birth weight (n/p)	29 (3.73)	17 (8.54)	0.004*
Delivery method			
VD (n/p)	374 (48.13)	81 (40.70)	0.041*
CS (n/p)	344 (44.27)	92 (46.23)	0.213
AVD (n/p)	9 (1.16)	3 (1.51)	0.690
sCS (n/p)	50 (6.44)	23 (11.56)	0.014*

Table 1 (*continued*)

Table 1 (*continued*)

Characteristic	Accurate estimation group (n=777, 79.61%)	Inaccurate estimation group (n=199, 20.39%)	P
GDM			
GDM (n/p)	217 (27.93)	54 (27.14)	0.824
OGTT (0 h) (mmol/L)	4.60±0.63	4.61±0.66	0.840
OGTT (1 h) (mmol/L)	8.00±1.99	7.98±2.02	0.903
OGTT (2 h) (mmol/L)	6.97±0.06	6.93±0.15	0.782
Hypertension disorders (n/p)	80 (10.3)	19 (9.55)	0.755
IVF (n/p)	55 (7.1)	16 (8.0)	0.641
Placenta previa (n/p)	36 (4.6)	7 (3.5)	0.494
Premature delivery (n/p)	24 (3.1)	9 (4.5)	0.318
Scarred uterus (n/p)	187 (24.1)	44 (22.1)	0.556
Hydramnios (n/p)	6 (0.8)	0 (0)	0.214
Oligoamnios (n/p)	7 (0.9)	1 (0.5)	0.578
Breech presentation (n/p)	18 (2.3)	3 (1.5)	0.483
Transverse presentation (n/p)	2 (0.3)	1 (0.5)	0.577
Female (n/p)	107 (53.8)	92 (46.2)	0.274
Male (n/p)	384 (49.4)	393 (50.6)	0.235

*, P value <0.05 was considered statistically significant. The data are presented as the mean ± standard deviation, the number and frequency, or the number and percentage. BMI, body mass index; BPD, biparietal diameter; HC, head circumference; AC, abdomen circumference; FL, femur length; EBW, estimation of birth weight; BW, birth weight; MAPE, mean absolute percentage error; MAD, mean absolute difference; GA, gestation age; LGA, large-for-gestational age infant; SGA, small-for-gestational age; AGA, appropriate-for-gestational age; n/p, n means number of cases, while P represents proportion accounting for corresponding group; VD, vaginal delivery; CS, cesarean section; AVD, assisted vaginal delivery; sCS, secondary cesarean section; GDM, gestational diabetes mellitus; OGTT, oral glucose tolerance test; IVF, in vitro fertilization; SD, standard deviation.

The overall accuracy rate of the SFWE predicted by the Hadlock IV formula was 79.61%, while that of the inaccurate estimation group was only 20.39%. The mean age of the patients in the accurate estimation group was 31.57±4.50 years, while that of the inaccurate estimation group was 30.87±4.00 years. There were statistically significant differences in the distribution of the fetal reclassification based on the BW and the distribution of the delivery methods between the 2 groups (P<0.05). As expected, the incidence of spontaneous VD was lower in the inaccurate estimation group than in the accurate estimation group (40.7% *vs.* 48.13%; P=0.041). In the inaccurate estimation group, 11.56% (23/199) of the patients underwent sCS compared to only 6.44% in the accurate estimation group. The proportions of SGA, macrosomia, and LBW infants were comparatively higher in the inaccurate estimation group (10.55%, 8.04%, and 8.54%, respectively) than in the accurate estimation group (5.02%, 4.38%, and 3.73%, respectively) (P<0.05). The value of the systemic mean PE was lower in the accurate estimation group (4.217%±2.66%) than in the inaccurate estimation group (13.65%±3.44%) (difference: 9.433%; P<0.0001). Other items, including the height, weight, and BMI of the pregnant women; birth time; GDM; hypertensive disorders; fetal sex; amniotic volume distribution; fetal presentation; and the ultrasound time interval did not differ significantly between the 2 groups in this study.

Univariate logistic regression analysis of the possible factors can influence SFWE

As shown in *Table 2*, prepregnancy and delivery BMI,

Table 2 Univariate logistic regression analysis of the possible factors can influence SFWE

Possible factor	Wald	P	OR	95% CI
Age (years)	4.035	0.045*	0.964	0.93–0.999
BMI pre-pregnancy	1.314	0.252	0.974	0.931–1.019
BMI delivery	1.214	0.270	0.975	0.931–1.02
Time interval	0.003	0.960	1.008	0.738–1.376
Gender	1.197	0.274	0.840	0.615–1.148
Delivery week	0.220	0.639	0.975	0.879–1.083
LGA	0.308	0.579	1.124	0.744–1.697
SGA	8.039	0.005*	0.448	0.257–0.78
AGA	4.634	0.031*	1.475	1.035–2.102
LBW	7.721	0.005*	0.415	0.223–0.772
Macrosomia	4.246	0.039*	0.523	0.283–0.969
GDM	0.050	0.824	1.041	0.734–1.476
Hypertension disorders	0.097	0.755	1.087	0.642–1.841
IVF	0.217	0.641	1.148	0.643–2.250
Placenta previa	0.465	0.495	0.750	0.329–1.712
Preterm birth	0.985	0.321	1.486	0.68–3.25
Scarred uterus	0.346	0.557	0.894	0.616–1.298
Polyhydramnios	0.000	0.999	0.000	0.00
Oligoamnios	0.301	0.583	0.556	0.068–4.542
Height	0.089	0.765	0.995	0.966–1.026
Preweight	3.216	0.073	0.985	0.969–1.001
Weight delivery	1.159	0.282	0.991	0.975–1.007
BPD	0.098	0.754	1.005	0.973–1.038
HC	1.388	0.239	0.993	0.982–1.005
AC	0.582	0.445	0.997	0.99–1.005
FL	1.109	0.292	0.977	0.935–1.02
Breech presentation	0.485	0.486	0.645	0.188–2.213
Transverse presentation	0.299	0.584	1.957	0.177–21.693

*, P value <0.05 was considered statistically significant. SFWE, sonographic-based fetal weight estimation; OR, odds ratio; CI, confidence interval; BMI, body mass index; BMI delivery, body mass index at delivery; LGA, large-for-gestational age infant; SGA, small-for-gestational age; AGA, appropriate-for-gestational age; LBW, low birth weight; GDM, gestational diabetes mellitus; IVF, in vitro fertilization; BPD, biparietal diameter; HC, head circumference; AC, abdomen circumference; FL, femur length.

prepregnancy and delivery weight and height, GA, IVF, the time interval between the ultrasound and birth, fetal presentation, gender of the fetus, implantation of placenta, ultrasound parameters (i.e., BPD, HC, AC, and FL), and amniotic volume were not statistically significant for SFWE (P=0.583) in our study. However, the other factors, including age, SGA, AGA, LBW, and macrosomia were statistically significant (P<0.05) in relation to SFWE accuracy.

Table 3 Multivariate logistic regression analysis of the possible factors can influence SFWE

Factor	Wald	P	OR	95% CI
Age (years)	3.103	0.078	0.968	0.934–1.004
SGA	3.307	0.069	0.500	0.237–1.055
AGA	0.031	0.860	0.954	0.566–1.608
Low birth weight	4.775	0.029*	0.483	0.252–0.928
Macrosomia	3.975	0.046*	0.459	0.214–0.987

*, indicates a P value <0.05. SFWE, sonographic-based fetal weight estimation; OR, odds ratio; CI, confidence interval; SGA, small-for-gestational age; AGA, appropriate-for-gestational age.

Table 4 Accuracy of SFWE among the different range weight groups of newborns

Category	Normal weight, n (%)	Macrosomia, n (%)	Low birth weight, n (%)	Sum, n (%)	P
Overestimation	516 (58.6)	12 (24.0)	30 (65.2)	558 (57.2)	<0.01
Underestimation	361 (41.0)	38 (76.0)	16 (34.8)	415 (42.5)	<0.01
Precise	3 (0.3)	0 (0.0)	0 (0.0)	3 (0.3)	<0.01
Sum	880 (100.0)	50 (100.0)	46 (100.0)	976 (100.0)	<0.01

SFWE, sonographic-based fetal weight estimation.

Multivariate logistic regression analysis of the possible factors can influence SFWE

Based on the results of the univariate logistic regression analysis of the possible factors (*Table 3*) and after adjustment for possible confounding variables (P>0.05), 5 indexes were chosen for inclusion in the multivariate logistic regression analysis. The multivariate analysis revealed that the inaccurate estimation group had significantly lower LBW rates and macrosomia rates than did the accurate estimation group, with ORs of 0.483 and 0.459 of LBW and macrosomia group, respectively (P<0.05). Thus, the SFWE was more accurate for the newborns with weights ranging from 2,500 to 4,000 g than for those out of this range.

Accuracy of SFWE among the different weight groups of newborns

To further examine the correlation between the accuracy of the SFWE and newborns of different weight ranges, we stratified the patients into different groups (*Table 4*). The results showed that for macrosomia, the SFWE was likely to be underestimated, but it was usually overestimated in the LBW group. The chi-squared test was adopted in this step, and both the columns (normal weight, macrosomia, LBW, sum) and rows (overestimation, underestimation, precise, and sum) were analyzed, with all the P values being <0.01.

Discussion

In this retrospective, single-center study of Chinese pregnant women, we compared the basic information between the accurate and inaccurate estimation groups. We also identified the factors affecting the SFWE and then examined the correlations between the accuracy of the SFWEs and newborns with different weight ranges. Consistent with previous research findings (7-9), we found that a higher rate of sCS was significantly correlated with a less accurate SFWE, which suggests that SFWE inaccuracies are more likely to be affected by the mode of delivery than by BW. Thus, a simple anticipation of deviations from the SFWE is likely to affect the management of labor and lead to a higher chance of sCS.

In our analysis, prepregnancy and delivery BMI, prepregnancy and delivery weight and height, GA, the use of IVF, the time interval between the ultrasound and birth, the fetal presentation, the BPD, the HC, the AC, the FL, and the amniotic volume were not found to be statistically related with SFWE, which is in line with the findings of several reports (5,10-13) but contradicts those of other

studies (14,15).

According to a review analysis (16), the mean accuracy rate of the SFWE ranged from 58.1% to 64.5% in full-term pregnant women; however, in our study, the mean accuracy rate reached 79.61%, which is much higher than that of other populations in other districts. Thus, the Hadlock IV formula remains unsatisfactory for Chinese women.

Similar to previous studies that have examined the accuracy of other formulas (17), we found that the FW had a significant effect on the accuracy of SFWE and was likely to overestimate the LBW of fetuses but underestimate macrosomia in fetuses. The Hadlock IV formula provided the most accurate predictions for Chinese newborns when the BW of the newborns ranged from 2,500 to 4,000 g. Thus, in cases where macrosomia is suspected or SFWE fluctuates between 2,500 and 4,000 g, obstetricians should be skeptical of the accuracy of any of the predicative values and consider using a different FW estimation method. Extra caution should be exercised in cases in which LGA, SGA, or LBW fetuses are suspected.

This study had a number of limitations. The first relates to the study's retrospective design. As all of the participants were treated at the same hospital, the sample cannot be considered representative. Additionally, the clinical estimation of the FW was not analyzed as a possible confounding variable in this study. Finally, as the total sample size of our study was not large and it was conducted at a single center, the results may not be widely generalizable.

Conclusions

We found that the overall performance of the Hadlock IV formula in predicting the weight of Chinese newborns was suboptimal. More research needs to be conducted to develop successful methods or formulas for estimating FW that are suitable to the Chinese population. There is a tendency for the Hadlock IV formula to overestimate the LBW of fetuses and underestimate macrosomia; thus, extra caution should be exercised in cases of suspected LGA, SGA, or LBW fetuses in the Chinese population.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-22-778/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-778/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Shanghai General Hospital, and individual consent for this retrospective analysis was waived.

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