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Original Article

Comparison of the accuracy of INTERGROWTH-21 formula with other ultrasound formulae in fetal weight estimation

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A R T I C L E I N F O

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A B S T R A C T

Objective: A new ultrasound formula for fetal weight estimation was proposed from the INTERGROWTH-21 project in 2017. There is no comparison of its accuracy with other ultrasound formulae. This study aims to compare the accuracy of INTERGROWTH-21 formula in fetal weight estimation with the traditional Hadlock1 and Shepard formula.

Materials and methods: All pregnant patients who had delivery in United Christian Hospital between January to December 2016 were retrospectively reviewed. Those who had prenatal ultrasound scan performed within 7 days of delivery were recruited. Hadlock1, Shepard and INTERGROWTH-21 formula were used to estimate the fetal weight and their accuracies were compared with the actual birthweight of neonates.

Results: A total of 403 patients were recruited. Hadlock1 was the most accurate with the lowest mean absolute percentage error (MAPE) 7.34 when compared with Shepard (9.00; $p < 0.001$) and INTERGROWTH-21 (9.07; $p < 0.001$). INTERGROWTH-21 had the lowest proportion of patients having estimated fetal weight within 10% discrepancy from the actual birthweight (57.6%) compared with Hadlock1 (71.2%; $p < 0.001$) and Shepard (66.3; $p = 0.011$). Presence of intrauterine growth restriction (IUGR) or fetal macrosomia (>=4000 g) were both associated with significantly higher MAPE in Hadlock1 and INTERGROWTH-21. IUGR ($p = 0.005$) and macrosomia ($p = 0.004$) remained significant in the final equation of logistic regression model that affect the precision of fetal weight estimation in Hadlock1, while only IUGR was significant in INTERGROWTH-21 ($p < 0.001$).

Conclusion: INTERGROWTH-21 formula was not shown to be better than the traditional Hadlock1 or Shepard formulae. Future prospective studies would be required to evaluate the accuracy of INTERGROWTH-21 formula especially at the extremes of birthweight.

Introduction

Birth weight is an important predictor of neonatal morbidities and mortalities [1]. Fetal weight estimation is an important parameter that affects antenatal management, particularly when this falls towards the two extremes. It will affect the timing of delivery for fetuses with intrauterine growth restriction (IUGR) and also those fetuses that at the limits of fetal viability [2]. Macrosomic fetuses have increased risk for shoulder dystocia, birth asphyxia and brachial plexuses injuries [3]; and accurate diagnosis of fetal macrosomia may change the choice of the mode of delivery. Sonographic measurement of fetal biometry is a commonly used method to estimate fetal weight with many different ultrasound formulae published in the literature. However, no particular ultrasound formula appears to be consistently more accurate or superior than the others [4].

The INTERGROWTH-21 and World Health Organization (WHO) had published international standard charts for fetal parameters including head circumference, bi-parietal diameter, occipital-frontal diameter, abdominal circumference and femur length in 2014 [5]. An international standard chart for estimated fetal weight was also published in 2017 and a new formula for fetal weight estimation based on the ultrasound biometry and the birth weight data from the project was proposed [6]. The objective of this study is to compare the accuracy of this newly developed ultrasound formula from the INTERGROWTH-21 project with two other commonly used formulae, namely Hadlock1 and Shepard formula,

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in estimating fetal weight and to explore any factors that will affect the accuracy of these ultrasound formulae.

Materials and methods

All pregnant patients who had delivery in the United Christian Hospital between January to December 2016 were retrospectively retrieved from the labour ward registry. These patients' antenatal ultrasound records were then reviewed from the obstetric computer database. Those who had prenatal ultrasound scan performed in the United Christian Hospital within 7 days of their delivery were then recruited. The patient's demographic data such as maternal age, body mass index, gestational age at delivery, the presence of pre-existing/gestational diabetes and IUGR were retrieved from the obstetric database and patients' case notes. The ultrasound parameters including fetal presentation, growth parameters, liquor volume and placental location were also retrieved. Hadlock1 and Shepard formula were the two most commonly used ultrasound formulae in Hong Kong. These were used together with INTERGROWTH-21 formula to calculate the estimated fetal weight and their accuracies were compared with the actual birthweight of the neonates. The possible factors that would affect the accuracy of the sonographic prediction of fetal weight were explored. The vast majority of our patients were Chinese. Non-Chinese patients were excluded from our study in order to keep our data homogeneous in ethnicity. Patients who had multiple pregnancies or intrauterine death were also excluded. Formal ethics approval for this study was granted by the Kowloon Central/Kowloon East Ethics Committee Board of the Hospital Authority, Hong Kong and patient consent is waived by the Ethics Committee as this is a retrospective study.

Hadlock1 formula was [7]:

$$\mathrm{Log}_{10}(\mathrm{EFW}) = 1.3596 + 0.0064 \times \mathrm{HC} + 0.0424 \times \mathrm{AC} + 0.174 \times \mathrm{FL} + 0.00061 \times \mathrm{BPD} \times \mathrm{AC} - 0.00386 \times \mathrm{AC} \times \mathrm{FL}\ [\mathrm{g,cm}]$$

Shepard formula was [8]:

$$\mathrm{Log}_{10}(\mathrm{EFW}) = -1.7492 + 0.166 \times \mathrm{BPD} + 0.046 \times \mathrm{AC} - 0.002546 \times \mathrm{AC} \times \mathrm{BPD}\ [\mathrm{kg,cm}]$$

INTERGROWTH-21 formula was [9]:

$$\mathrm{Log}_{e}(\mathrm{EFW}) = 5.084820 - 54.06633 \times (\mathrm{AC}/100)^3 - 95.80076 \times (\mathrm{AC}/100)^3 \times \log_e(\mathrm{AC}/100) + 3.136370 \times (\mathrm{HC}/100)\ [\mathrm{g,cm}]$$

EFW denotes estimated fetal weight; BPD denotes bi-parietal diameter; HC denotes head circumference; AC denotes abdominal circumference; FL denotes femur length.

The accuracy of the different formulae was compared by the mean of their percentage error.

$$\text{Percentage error} = (\mathrm{EFW} - \mathrm{BW}) / \mathrm{BW} \times 100$$

EFW denotes estimated fetal weight; BW denotes the actual birth weight of the neonate on delivery.

The mean of the percentage error was considered as marker for the systematic error and the corresponding standard deviation as marker for the random error. The systematic error reflects the tendency of an equation to under- or overestimate fetal weight, while random error is a measure of the precision of an equation. As systematic error is calculated using positive value for overestimations and negative values for underestimations, the mean percentage error will cancel out the over- and under-estimations. Therefore, the mean absolute percentage error (MAPE) is generally used in calculations to compare the accuracy of the different ultrasound formulae which was similar to previous studies [4,9–12].

$$\text{Absolute percentage error} = |\mathrm{EFW}\text{-}\mathrm{BW}| / \mathrm{BW} \times 100$$

SPSS version 23.0 was used for data entry and analysis. The differences of continuous variables were analyzed using *t*-test. The differences of discrete variables were analyzed by Chi-square test or Fisher's exact test when appropriate. P value of less than 0.05 ($P < 0.05$) was considered as statistically significant.

Results

During the study period, there were a total of 4337 deliveries with 79 pairs of twins in United Christian Hospital. A total of 423 singleton pregnancies had prenatal ultrasound scan performed within 7 days of delivery. Twenty patients were excluded due to they were non-Chinese. Therefore, 403 patients were eligible for final analysis. The ultrasound scan was performed by 16 operators and all of them were qualified prenatal ultrasound operators according to our local obstetric ultrasound training and accreditation system. The median gestational age at delivery was 37.7 week. The median time interval between ultrasound and delivery was 3 days. The median actual birthweight of the neonates was 2680 g. The demographic data was shown in Table 1.

Hadlock1 formula was found to be the most accurate compared with Shepard and INTERGROWTH-21 formula. The MAPE was 7.34, 9.00 and 9.07 for Hadlock1, Shepard and INTERGROWTH-21 formula respectively. Hadlock1 formula had significantly lower MAPE compared with Shepard ($p < 0.001$) and INTERGROWTH-21 formula ($p < 0.001$) respectively, while no statistically significant difference was seen between Shepard and INTERGROWTH-21 formulae. Using Hadlock1 formula, 71.2% of the patients had the estimated fetal weight falling within ± 10% discrepancy range of the actual birthweight. Using Shepard and INTERGROWTH-21 formula, 66.3% and 57.6% of patients had estimated fetal weight within the 10% discrepancy range. The proportion of patients with estimated fetal weight within the 10% discrepancy range was significantly

Table 1
Demographic data and sonographic characteristics of all the 403 patients.

Demographic data	Median (Range)	SD
Maternal age (years)	32.0 (18.0–45.0)	5.61
BMI at booking visit (kg/m^2)	21.5 (14.5–32.0)	3.56
Gestational age at delivery (weeks)	37.7 (24.1–41.3)	3.39
Interval between ultrasound and delivery (days)	3.0 (0.0–7.0)	2.16
Actual fetal birth weight (g)	2680 (524–4498)	787
Sonographic characteristics	**Number (%)**	
Time between ultrasound and delivery		
<=3 days	257 (63.7%)	
4–5 days	68 (16.9%)	
6–7 days	78 (19.4%)	
Presence of IUGR	67 (16.6%)	
Birth weight < 1500 g	37 (9.2%)	
Birth weight <2500 g	147 (36.5%)	
Macrosomia (≥ 4000 g on birth)	12 (3.0%)	
Maternal obesity (Booking BMI ≥ 25)	82 (20.3%)	
Maternal diabetes	70 (17.4%)	
Pre-eclampsia	41 (10.2%)	
Intact membranes on the day of ultrasound scan	353 (87.6%)	
Oligohydramnios (AFI <8 cm)	115 (28.5%)	
Cephalic presentation	335 (83.1%)	
Anterior- locating placenta	176 (43.7%)	
Male fetuses	213 (52.9%)	

SD, standard deviation; BMI, body mass index; IUGR, intrauterine growth restriction (which defined as no fetal growth between 2 or more ultrasound scans performed at least 14 days apart); AFI, amniotic fluid index.

lower in INTERGROWTH-21 formula when compared with Hadlock1 formula ($p < 0.001$) and Shepard formula ($p = 0.011$). The proportion of patients with estimated fetal weight within ± 15% of actual birth weight was also significantly higher for Hadlock1 formula (94.5%) than Shepard formula (78.2%, $p < 0.001$) and INTERGROWTH-21 formula (79.9%, $p < 0.001$). (Table 2).

Different factors that may affect the accuracy of sonographic estimation of fetal weight by Hadlock1, Shepard and INTERGROWTH-21 formula were analyzed (Table 3). Presence of intrauterine growth restriction (IUGR) or fetal macrosomia (birth weight ≥ 4000 g) were both associated with significantly higher absolute percentage error when using either Hadlock1 or INTERGROWTH-21 formula. Using Hadlock1 formula, the MAPE was significantly higher for those babies with IUGR compared to those without (9.10 vs 6.99, $p = 0.002$), as was for INTERGROWTH-21 formula (14.11 vs 8.07; $p < 0.001$). Similarly, the MAPE was found to be significantly higher in the presence of fetal macrosomia compared to those without when using Hadlock1 formula (12.27 vs 7.19, $p = 0.001$) and INTERGROWTH-21 formula (15.18 vs 8.89, $p = 0.002$). However, fetal birth weight <1500 g and <2500 g were not found to have significant difference on the MAPE in all the three ultrasound formulae.

Maternal conditions including obesity, diabetes and pre-eclampsia were not shown to affect the MAPE in sonographic estimation of fetal weight in all the three ultrasound formulae, nor were other ultrasound characteristics including oligohydramnios, non-cephalic presentation and anterior-locating placenta. The MAPE was not significantly affected between patients with or without rupture of membranes, nor between male and female fetuses.

A stepwise logistic regression model was constructed for all the three ultrasound formulae using whether the estimated fetal weight fell within the 10% discrepancy range of the actual birthweight as the dependent variable against parameters found to be significant on univariate analysis including IUGR and macrosomia (Table 4). When Hadlock1 formula was used, IUGR ($p = 0.005$) and macrosomia ($p = 0.004$) remained significant in the final equation. When INTERGROWTH-21 formula was used, IUGR ($p < 0.001$) remained significant after the stepwise logistic regression but not for macrosomia ($p = 0.998$).

Discussion

Using the MAPE and the proportion of patients who had the estimated fetal weight within 10% discrepancy from the actual birthweight as performance indicators, our data showed that the accuracy of the different formulae were similar to what was reported in the literature. The traditional Hadlock1 formula apparently performed best with the lowest MAPE and highest in range proportion, while the performance of the new INTERGROWTH-21 formula was apparently inferior to the traditional formulae within this cohort.

The accuracy of different ultrasound formulae has been compared in various studies in the literature, but comparisons with the INTERGROWTH-21 formula have not been studied so far. A study published in 2016 had investigated the accuracy of 35 different ultrasound formulae in 3416 fetuses. Its MAPE for Hadlock1 formula was 7.5 with 71.4% patients having the discrepancy of the estimated fetal weight with the actual birthweight within 10%. The MAPE for Shepard formula was 8.5 with 65.7% of patients having the discrepancy of the estimated fetal weight with the actual birthweight within 10% [9]. Another study published in 2015 investigated the accuracy of 18 ultrasound formulae in 495 fetuses. Its MAPE for Hadlock1 formula was 7.7 while for Shepard formula was 9.2, though the percentage of patients who had the discrepancy of the estimated fetal weight and the actual birthweight within 10% was not reported [13]. These figures were very close to our current findings, and reflected that the standards and performance of our sonographers were probably also very similar to these studies. Therefore, using the same set of fetal biometry data from our cohort to estimate the fetal weight using the INTERGROWTH-21 formula should not lead to particularly over- or underestimation of its accuracy.

Our data showed that the newly developed INTERGROWTH-21 formula did not perform any better than the traditional Hadlock1 formula. Studies showed that the accuracy in fetal weight estimation was highest when the ultrasound examinations were performed within 7 days before delivery and it significantly decreased after 7 days [11,12]. The INTERGROWTH-21 project included patients who had ultrasound scan within 14 days of birth for calculations and the formula for estimated fetal weight was derived from this group of patients. Therefore, it could be postulated that the accuracy of INTERGROWTH-21 formula was lowered due to the more heterogeneous data resulting from the inclusion of patients with ultrasound scan more than 7 days before delivery with differential variations in subsequent fetal growth and weight changes before delivery.

Although Hadlock1 formula had the lowest MAPE compared with Shepard and INTERGROWTH-21 formula, its accuracy was found to be significantly lower in fetuses with macrosomia and IUGR in our study. A previous study had compared different ultrasound formulae in fetuses with birth weight >4000 g and found Hadlock1 was less accurate than many other ultrasound formulae [9]. It was also reported that Hadlock1 formula had the highest accuracy when compared with 17 other ultrasound formulae in estimating fetuses with actual birthweight between 2500 g and 4000 g. However, its accuracy decreased significantly in macrosomic fetuses (>4000 g) and in low birth weight fetuses (>2500 g)

Table 2
Comparison of the accuracy of the three ultrasound formulae.

The accuracy indicators	Hadlock1	Shepard	INTERGROWTH-21	Hadlock1 vs Shepard P value; MD (CI)	Hadlock1 vs INTERGROWTH-21 P value; MD (CI)	Shepard vs INTERGROWTH-21 P value; MD (CI)
Mean percentage error % ± SD	−4.28 ± 7.85	5.49 ± 10.35	−6.46 ± 9.44	[a]<0.001; − 9.77 (−11.1 to −8.43)	[a]<0.001; 2.18 (0.98–3.44)	[a]<0.001; 11.95 (10.58–13.3)
MAPE % ± SD	7.34 ± 5.09	9.00 ± 7.50	9.07 ± 6.96	[a]<0.001; −1.66 (−2.55 to −0.77)	[a]<0.001; −1.73 (−2.57 to −0.89)	0.89; −0.07 (−1.07 to 0.93)
Number (%) of patients had EFW within 10% of actual birthweight	287 (71.2%)	267 (66.3%)	232 (57.6%)	0.129	[a]<0.001	[a]0.011
Number (%) of patients had EFW within 15% of actual birthweight	381 (94.5%)	315 (78.2%)	322 (79.9%)	[a]<0.001	[a]<0.001	0.545

vs, versus; MD, mean difference; SD, standard deviation; CI, confidence interval; MAPE, mean absolute percentage error; EFW, estimated fetal weight.
[a] Statistically significant.

Table 3
Factors that may affect the accuracy of the absolute percentage error of the three ultrasound formulae.

Factors that may affect the accuracy		Hadlock1		Shepard		INTERGROWTH-21	
		Mean of the APE ± SD	P value; MD (95% CI)	Mean of the APE ± SD	P value; MD (95% CI)	Mean of the APE ± SD	P value; MD (95% CI)
IUGR	Yes	9.10 ± 5.76	[a]0.002; 2.10 (0.78–3.43)	7.06 ± 5.19	[b]0.020; −2.32 (−4.28 to −0.36)	14.11 ± 8.20	[a]<0.001; 6.04 (4.31–7.77)
	No	6.99 ± 4.88		9.38 ± 7.83		8.07 ± 6.22	
Birthweight <1500 g	Yes	6.19 ± 4.29	0.149; −1.27 (−2.99 to 0.46)	7.99 ± 9.66	0.390; −1.11 (−3.66 to 1.43)	9.62 ± 6.32	0.614; 0.61 (−1.75 to 2.97)
	No	7.46 ± 5.16		9.10 ± 7.25		9.02 ± 7.02	
Birthweight <2500 g	Yes	6.93 ± 5.03	0.216; −0.65 (−1.69 to 0.38)	8.96 ± 7.41	0.940; −0.06 (−1.59 to 1.47)	9.72 ± 6.93	0.155; 1.02 (−0.39 to 2.44)
	No	7.58 ± 5.12		9.02 ± 7.56		8.70 ± 6.96	
Macrosomia (birthweight ≥ 4000 g)	Yes	12.27 ± 5.73	[a]0.001; 5.08 (2.18–7.97)	5.48 ± 5.63	0.099; −3.63 (−7.94 to 0.68)	15.18 ± 3.62	[a]0.002; 6.29 (2.33–10.26)
	No	7.19 ± 5.00		9.11 ± 7.53		8.89 ± 6.95	
Booking BMI ≥ 25	Yes	6.61 ± 5.75	0.143; −0.92 (−2.16 to 0.31)	7.82 ± 7.02	0.110; −1.48 (−3.31 to 0.34)	8.49 ± 6.93	0.392; −0.74 (−2.43 to 0.96)
	No	7.53 ± 4.90		9.30 ± 7.60		9.22 ± 6.96	
Maternal diabetes	Yes	7.05 ± 6.39	0.603; −0.35 (−1.67 to 0.97)	7.55 ± 5.44	0.076; −1.75 (−3.68 to 0.19)	8.19 ± 7.45	0.246; −1.06 (−2.86 to 0.73)
	No	7.40 ± 4.78		9.30 ± 7.83		9.26 ± 6.84	
Pre-eclampsia	Yes	5.95 ± 4.70	0.064; −1.55 (−3.20 to 0.09)	10.86 ± 9.56	0.093; 2.07 (−0.35 to 4.50)	8.45 ± 7.01	0.548; −0.69 (−2.94 to 1.57)
	No	7.50 ± 5.12		8.79 ± 7.21		9.14 ± 6.95	
Rupture of membranes	Yes	6.46 ± 4.84	0.193; −1.00 (−2.51 to 0.51)	9.20 ± 7.27	0.838; 0.23 (−2.00 to 2.46)	8.63 ± 5.55	0.631; −0.51 (−2.57 to 1.56)
	No	7.47 ± 5.12		8.97 ± 7.54		9.14 ± 7.14	
Oligohydramnios (AFI < 8 cm)	Yes	7.52 ± 5.04	0.651; 0.25 (−0.85 to 1.36)	7.97 ± 6.98	0.082; −1.44 (−3.06 to 0.18)	10.12 ± 6.76	0.055; 1.47 (−0.03 to 2.97)
	No	7.27 ± 5.12		9.41 ± 7.67		8.65 ± 7.00	
Non-cephalic presentation	Yes	6.39 ± 5.45	0.092; −1.14 (−2.47 to 0.19)	9.12 ± 8.82	0.882; 0.15 (−1.81 to 2.11)	8.71 ± 7.52	0.634; −0.44 (−2.26 to 1.38)
	No	7.53 ± 5.00		8.97 ± 7.22		9.15 ± 6.84	
Anterior-locating placenta	Yes	6.87 ± 4.01	0.104; −0.83 (−1.84 to 0.17)	9.69 ± 8.21	0.103; 1.23 (−0.25 to 2.71)	8.58 ± 5.97	0.214; −0.87 (−2.24 to 0.50)
	No	7.70 ± 5.77		8.46 ± 6.87		9.45 ± 7.63	
Male fetuses	Yes	7.51 ± 5.25	0.485; 0.36 (−0.64 to 1.35)	8.58 ± 7.05	0.235; −0.89 (−2.36 to 0.58)	9.09 ± 6.78	0.954; 0.04 (−1.33 to 1.41)
	No	7.15 ± 4.92		9.47 ± 7.96		9.05 ± 7.17	

APE, absolute percentage error; SD, standard deviation; CI, confidence interval; IUGR, intrauterine growth restriction; BMI, body mass index; AFI, amniotic fluid index.
[a] Statistically significant in decreasing the accuracy.
[b] Statistically significant in increasing the accuracy.

Table 4
Logistic regression analysis of the factors that affect the proportion of patients who had estimated fetal weight within 10% discrepancy range of actual birthweight in all three ultrasound formulae.

Factors that may affect the accuracy	B	SE	Wald	P value	Odds ratio	95% CI	
						Upper	Lower
Hadlock1							
IUGR	−0.784	0.279	7.881	[a]0.005	0.457	0.264	0.789
Macrosomia	−1.808	0.626	8.350	[a]0.004	0.164	0.048	0.559
Shepard							
IUGR	0.602	0.309	3.798	0.051	1.826	0.997	3.345
Macrosomia	1.052	0.783	1.805	0.179	2.864	0.617	13.292
INTERGROWTH-21							
IUGR	−1.493	0.291	26.231	[a]<0.001	0.225	0.127	0.398
Macrosomia	−21.841	11,602	0.000	0.998	0.000	0.000	–

CI, confidence interval; IUGR, intrauterine growth restriction.
[a] Statistically significant.

[13]. In addition, comparing the error among 12 ultrasound formulae when the actual fetal birthweight was divided into 4 groups: <1000 g, 1000–1999g, 2000–2999 g and >3000 g, the error rate of Hadlock1 formula was found to increase when the actual fetal birthweight was <1000 g [14]. The limitations of the Hadlock1 formula at both extremes of birthweight apparently also apply to INTERGROWTH-21 formula. The MAPE was significantly increased in IUGR fetuses and macrosomic fetuses using INTERGROWTH-21 formula in this study, and IUGR remained a significant factor affecting the precision of fetal weight estimation in the logistic regression analysis. Therefore, if INTERGROWTH-21 formula was applied on patients with extremes in fetal weight, similar to Hadlock1 formula, larger errors in estimation of fetal weight should be expected.

In our data, while that Shepard formula has lower MAPE compared to Hadlock1 formula in general, its accuracy was not decreased in fetuses with macrosomia or IUGR. A study compared the accuracy of 8 ultrasound formulae to estimate fetal weight on 1099 fetuses and Shepard formula was most consistently found to give the lowest systematic and random errors throughout all weight categories [15]. Therefore, Shepard formula may be a better choice to estimate fetal weight when the fetus is in the extreme ends of the birthweight. A group of researchers suggested a two-step procedure for weight estimations with reference to the extremes of actual birthweight. It was suggested by some to measure the abdominal circumference as the first-step, then a specific ultrasound formula was used to estimate the fetal weight base on the measurement of the abdominal circumference. A particular formula could be used when the abdominal circumference was less than 290 mm, or when the abdominal circumference was larger than 360 mm [16,17]. Zurich method was invented to multiply the abdominal circumference with the femur length. If the value is < 24,600, Hadlock formula could be used, while if the value was >24,600, Merz formula should be used. This method was shown to be able to correct the error of Hadlock formula in fetuses ≥ 3500 g [18]. From our data, it could be argued that we should use Shepard formula instead of Hadlock1 formula when the fetus was known to be growth restricted; or when the estimated fetal weight by Hadlock1 formula was >4000 g, Shepard formula could be used to re-estimate fetal weight again to avoid underestimations. This approach seems to be simpler than the Zurich method. The specific weaknesses of INTERGROWTH-21 formula should be further explored to decide whether the Zurich approach or other modifications should also apply using a larger prospective cohort.

Some previous studies have shown that sonographic estimation of fetal weight could be affected by specific characteristics of the pregnancy, such as fetal gender [19] or fetal presentation [20]. Our data showed that the accuracy of all the three ultrasound formulae was not affected by maternal obesity, liquor volume, ruptured or intact membranes, the fetal presentation, the location of the placenta, nor the fetal gender, and our findings were compatible with most other studies in the literature [21–25]. We believe that these factors should not in general significantly affect the accuracy of the estimation if the ultrasound formulae have been derived from a sufficiently large database that was unbiased towards these specific factors. In particular, similar to the traditional formulae, INTERGROWTH-21 formula has not shown any particular bias towards these parameters.

The strengths of this study included the homogeneity of our cohort with all ultrasound parameters being taken within 7 days of delivery. However, the limitations of our data included the relatively small sample size based on a southern Chinese population, and the percentage of patients with extremes in birthweight was in proportion to the general obstetric population. A larger sample size conducted prospectively may provide more information about the accuracy of the different ultrasound formulae, and specific collection of more data on extremes in birthweight might be needed to explore the strengths and weaknesses of INTERGROWTH-21 formula.

In conclusion, our data was unable to show any advantage in using INTERGROWTH-21 formula for fetal weight estimation as compared to the traditional Hadlock1 or Shepard formulae. Further studies with larger sample sizes in different populations would be required to prove the accuracy of INTERGROWTH-21 formula before it can be put forward for general clinical application or for substitution of other ultrasound formulae.

Conflicts of interests

The authors have no conflicts of interest relevant to this article.

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