Ultrasound versus Clinical Examination to Estimate Fetal Weight at Term

Vergleich von Ultraschall und klinischer Untersuchung zur fetalen Gewichtsschätzung am Geburtstermin

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Key words
fetal weight estimation, ultrasound, clinical examination

Schlüsselwörter
fetale Gewichtsschätzung, Ultraschall, klinische Untersuchung

received 29. 10. 2016
revised 22. 1. 2017
accepted 25. 1. 2017

Bibliography
DOI http://dx.doi.org/10.1055/s-0043-102406
Geburtsh Frauenheilk 2017; 77: 276–283 © Georg Thieme Verlag KG Stuttgart · New York | ISSN 0016-5751

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ABSTRACT

Introduction At term, fetal weight estimation is an important factor for decisions about the delivery mode and the timing of labor induction. This study aimed to compare the accuracy of abdominal palpation with that of ultrasound performed by different examiners to estimate fetal weight. The study investigated whether differences in the examiners' training affected fetal weight estimates. The accuracy of the weight estimates made for fetuses with extreme birth weights was also evaluated. Finally, the accuracy of Johnson's method and of Insler and Bernstein's formula for estimating fetal weight were compared with the other two methods.

Methods This prospective study included singleton pregnancies between 37 weeks of gestation and 12 days post-term planned for vaginal delivery or cesarean section. Ultrasound and abdominal palpation using Leopold's maneuvers were performed by examiners with different levels of professional experience. Fetal weight was additionally estimated using Insler and Bernstein's formula and Johnson's method. Statistical analysis calculated the accuracy of fetal weight estimates for the different examiners and the four methods.

Results A total of 204 women were included in the analysis. Trained ultrasound examiners were most accurate when estimating fetal weight compared with all other examiners. The comparison of all four methods showed that fetal weight was assessed most accurately with ultrasound. No learning curve could be established. BMI and advanced gestational age affected the accuracy of the estimated weight. The analysis showed that a greater deviation between estimated weight and actual weight occurred with all four methods for fetuses at either end of the extremes of fetal weight, i.e., with very low or very high birth weights.

Conclusion Fetal weight should be estimated using ultrasound. A good ultrasound training is essential.

ZUSAMMENFASSUNG

Einleitung Am Geburtstermin liefert die fetale Gewichtsschätzung wichtige Daten für die Entscheidungsfindung in Bezug auf den Entbindungsmodus und den Zeitpunkt der Geburtseinleitung. Ziel dieser Studie war es, die Genauigkeit zweier Methoden – der abdominellen Palpation und des Ultraschalls – bei der Schätzung des fetalen Gewichts zu vergleichen. Die Untersuchungen wurden jeweils von verschiedenen medizinischen Untersuchern durchgeführt. Es wurde untersucht, ob die unterschiedlichen Ausbildungsniveaus der Untersucher sich auf die Genauigkeit der fetalen Gewichtsschätzung auswirkten. Die Genauigkeit der Gewichtsschätzung bei Feten mit extrem hohem oder niedrigem Geburtsgewicht wurde ebenfalls ausgewertet. Schließlich wurde die Genauigkeit von Johnsons Methode und von Inslers und Bernsteins Formel zur Schätzung des fetalen Gewichts mit den anderen beiden Methoden verglichen.

Methoden Alle Einlingsschwangerschaften zwischen der 37. Schwangerschaftswoche und dem 12. Tag nach dem errechneten Geburtstermin, bei denen entweder eine vaginale Entbindung oder eine Sectio caesarea geplant waren, wurden in diese prospektive Studie aufgenommen. Die Ultraschalluntersuchung und die mithilfe von Leopold-Handgriffen durchgeführte abdominelle Palpation wurden von Untersuchern mit unterschiedlicher Berufserfahrung durchgeführt. Das fetale Gewicht wurde auch mithilfe der Formel von Insler und Bernstein sowie mit Johnsons Methode geschätzt. Die Genauigkeit der fetalen Gewichtsschätzung zwischen den verschiedenen Untersuchern sowie zwischen den 4 Methoden wurde statistisch verglichen.

Ergebnisse Insgesamt wurden 204 Frauen in die Studie eingeschlossen. Der Vergleich zeigte, dass von allen Untersuchern die Ultraschalluntersucher das fetale Gewicht am besten abschätzen konnten. Beim Vergleich der Schätzmethode stellte sich heraus, dass Ultraschall wiederum die genauesten Schätzungen lieferte. Die statistische Analyse konnte keine Lernkurve ermitteln. BMI und fortgeschrittenes Schwangerschaftsalter wirkten sich auf die Genauigkeit der Gewichtsschätzung aus. Bei allen 4 Methoden trat die größte Abweichung zwischen dem geschätzten und dem tatsächlichen Gewicht bei Feten mit entweder extrem hohem oder extrem niedrigem Gewicht auf.

Schlussfolgerung Das fetale Gewicht sollte mit Ultraschall geschätzt werden. Eine gute Ultraschallausbildung ist unerlässlich.

Introduction

Estimating fetal weight during pregnancy is an important aspect of prenatal and intrapartum care [1]. Towards the end of pregnancy, fetal weight estimation becomes even more important for planning the birth, as perinatal complications are higher in cases where the birth weight is at either end of the extremes. During routine appointments, fetal weight estimates can influence the decisions about the mode of delivery and the timing of labor induction. Accurate estimates are essential, since abnormal fetal growth may be associated with perinatal and maternal risk. Delivery of a macrosomic fetus is associated with prolonged labor and various delivery traumas, including shoulder dystocia, brachial plexus injuries and intrapartum asphyxia, as well as increased maternal risks such as birth canal injuries and postpartum hemorrhage [2–4]. At the other extreme, it is important to identify a growth-restricted fetus to determine the control interval and the time of delivery in order to minimize perinatal risks, including intrauterine fetal death and neonatal morbidity [5].

To provide the best perinatal management, obstetricians should use the examination technique that most accurately estimates fetal weights. The method should additionally be simple, valid and reliable. The two most commonly used methods to estimate fetal weight are ultrasound and clinical examination. Currently, ultrasound is preferred because of its ease of use, objectivity and precision. The most commonly used formula is Hadlock's formula, which includes fetal head circumference, abdominal circumference, and femur length [6]. Nevertheless, irrespective of the regression equation used, fetal weight estimates done by ultrasound show measurement variations of up to ± 6–11 % at or near term [7, 8].

In countries where ultrasound is not available, fetal weights are estimated by abdominal palpation of fetal body parts using Leopold's maneuvers, by measuring fundal height and maternal abdominal circumference (Insler and Bernstein's formula) and using Johnson's method. Johnson's method and Insler and Bernstein's formula are both formulas that estimate fetal weight by using easily obtained clinical maternal measurements [9–13]. Although all of these methods have been extensively reviewed, there is still disagreement in the current literature about their accuracy, and there is still a debate about which method is the most reliable and valid.

This study aimed to compare the accuracy of the two most commonly used techniques, abdominal palpation and ultrasound, carried out near to and at term. The investigation also looked at whether differences in examiner training affected fetal weight estimates and whether there was a learning curve involved with either method. The study also investigated whether there were differences in weight estimates caused by the fetus having an extreme birth weight (very high or very low), and, given the increasing prevalence of obesity, particularly in Western society, whether maternal BMI influenced fetal weight estimates. Finally, the accuracy of Johnson's method and of Insler and Bernstein's formula for estimating fetal weight were assessed and compared to the other two methods.

Methods

Study population

This prospective study was carried out over a one-year period, from January 2015 to December 2015, in the Department of Gynecology and Obstetrics of the Hanover Medical School and was approved by the Ethics Committee of the Hanover Medical School. The study included women with singleton pregnancies in cephalic presentation scheduled for normal vaginal delivery or cesarean section, who were between 37 weeks of gestation and 12 days post-term. Exclusion criteria were non-cephalic singleton pregnancies, multiple pregnancies, fetal anomalies, all pregnancies of less than 37 weeks of gestation, and intrauterine fetal death. Women who agreed to participate in the study but delivered more than 5 days after fetal weight estimation were excluded from the analysis.

Fetal weight estimation by ultrasound

After obtaining informed consent from the participants, fetal weight estimation was done twice, first by ultrasound and then by abdominal palpation. The same high-end ultrasound machine (GE, Voluson E, 3.5-MHz abdominal transducer) was used by all examiners. Femur length, biparietal diameter and fronto-occipital diameter were measured to calculate head circumference, and abdominal transverse and sagittal diameters were measured to calculate abdominal circumference (AC). These measurements were entered into the database (Viewpoint database) to calculate fetal weight using Hadlock's formula. Ultrasound to estimate fetal weight was carried out by three examiners. The first examiner (E1) was an ultrasound specialist with more than 10 years' professional experience. The second examiner (E2) and the third examiner (E3) were both residents. E2 had been intensively trained in ultrasound skills for 6 months by E1, whereas E3 had been taught the basic measuring planes over 10 days and had additionally learned by observation before the study. Both residents were in the second year of a 5-year residency program.

Fetal weight estimation by clinical examination

Fetal weight estimates using abdominal palpation were made by four examiners: a consultant with more than 10 years' professional experience (E4), a consultant with more than 20 years' professional experience (E5), a resident in the third year of residency (E6), and a midwife with more than 10 years' professional experience (E7). The examiners used Leopold's maneuvers. Symphysis-fundal height (SFH) measurement was done from the mid-point of the upper border of the maternal pubic symphysis to the highest point on the uterine fundus. Maternal abdominal circumference was measured at the level of the umbilicus. Measurements were taken using a flexible tape calibrated in cm. Fetal weight was calculated using Insler and Bernstein's formula: fetal weight (g) = SFH (cm) × AC (cm) [10]. Fetal weight was also determined with Johnson's method [11]: fetal weight (g) = (fundal height [cm] – n) × 155. In 13 cases, the presenting part was not engaged; in 12 cases, the presenting part was above the ischial spine/at 0 station; in 11 cases, the presenting part was below the ischial spine/

at + 1 station. If the mother weighed more than 91 kg, 1 cm was subtracted from the fundal height.

None of the examiners were told about the other examiners' estimates or the mother's hospital records; only gestational age and parity were provided prior to examination. Each newborn was weighed within an hour of birth using the same weighing scales (seca), which are automatically calibrated on a regular basis. Maternal age, gestational age, BMI and parity were recorded, as were neonatal details, including birth weight and delivery date.

Statistical analysis

Statistical analysis was performed using the statistics software program R (http://www.cran.r-project.org) and were done in collaboration with the Statistical Institute of the University of Hanover. Demographic details are given as either means or percentages.

To compare estimated fetal weights with the actual birth weights, the minimum, first quartile, median, arithmetic medium, third quartile, maximum, standard deviation and mean square error were calculated for each examiner. Mean square error is a measure that compares the estimated weight with the actual birth weight. The Kullback-Leibler divergence was used to demonstrate how close each estimated fetal weight was to the actual birth weight. First, the Diebold-Mariano test was used to compare the accuracy of fetal weight estimates among the examiners and between ultrasound and abdominal palpation. Based on the differences between estimated and actual weights, the Goldfeld-Quandt test was used to calculate the variance of the differences measured among examiners. A possible learning effect and potential factors influencing fetal weight estimation were analyzed using Pearson's correlation coefficient and a linear regression model. Statistical significance was achieved when $p < 0.05$.

In a second step, the accuracy of all four methods (ultrasound, abdominal palpation, Johnson's method, and Insler and Bernstein's formula) was analyzed. In addition to descriptive statistics, mean square error, Kullback-Leibler divergence, sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV) and receiver operating characteristic (ROC) curves were calculated. Sensitivity, specificity, NPV and PPV were initially determined for a variation in weight of up to 1000 g, followed by a calculation for a variation in weight of up to 500 g.

▶ **Table 1** Demographics details.

Demographic details n = 204	
Maternal characteristics	
Maternal age [in years]: median (range)	31.6 (16.0–45.0)
Weeks of gestation: median (range)	39.7 (37.0–42.0)
BMI [kg/m²]: median (range)	30.8 (19.9–53.0)
BMI – normal weight [18.5 < BMI < 24.99]: n (%), mean (range)	23 (11.3 %), 23.2 (19.9–24.8)
BMI – overweight [25.0 < BMI < 29.99]: n (%), mean (range)	80 (39.2 %), 27.7 (25.1–29.8)
BMI – obesity class I [30.0 < BMI < 34.9]: n (%), mean (range)	66 (32.4 %), 32.2 (30.0–34.9)
BMI – obesity class II [35.0 < BMI < 39.9]: n (%), mean (range)	21 (10.3 %), 36.5 (35.2–39.7)
BMI – obesity class III [BM > 40.0]: n (%), mean (range)	14 (6.9), 44.3 (40.6–53.0)
Primiparous: n (%)	113 (55.4 %)
Multiparous: n (%)	92 (45.1 %)
Ethnicity	
White: n (%)	199 (97.4 %)
Black: n (%)	3 (1.5 %)
Asian: n (%)	2 (0.9 %)
Maternal comorbidities	
Gestational diabetes: n (%)	33 (16.1 %)
Pregnancy-induced hypertension: n (%)	5 (2.5 %)
Thrombophilia: n (%)	9 (3.6 %)
None: n (%)	158 (77.5 %)
Neonatal characteristics	
Birth weight [g]: median (range)	3 575.9 (2 200–5 050)
Neonatal length [cm]: median (range)	52.8 (46–59)
Neonatal head circumference [cm]: median (range)	35.3 (31.5–39.0)
Female gender: n (%)	94 (46.1 %)
Male gender: n (%)	110 (53.9 %)

Results

A total of 204 women were included in the analysis. The study population's demographic details are given in ▶ **Table 1**.

Fetal weight estimation: ultrasound versus palpation

The weight estimates made by all examiners were compared to the actual birth weights. ▶ **Table 2** shows the descriptive statistics for this comparison and the Kullback-Leibler divergence.

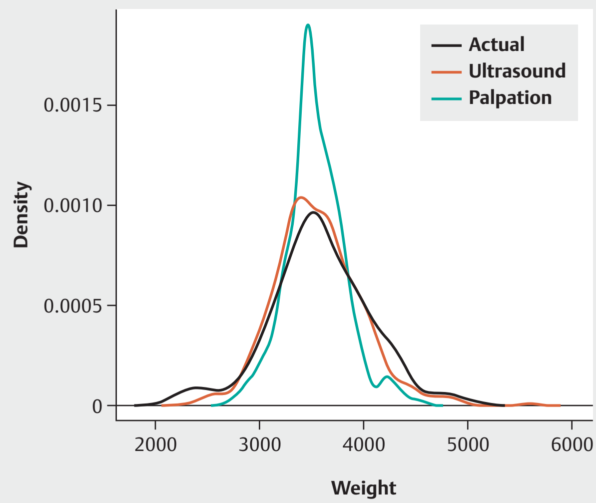
The mean square error of all examiners in the palpation group was significantly higher than in the ultrasound group, with the exception of ultrasound examiner E3 who had the highest mean square error. The smallest predictive errors were those of ultrasound examiners E1 and E2. Fetal weight estimates were performed most accurately by E1, followed by E2.

Of the examiners who used abdominal palpation to estimate weights, E4 and E7 were more accurate than E5 and E6, and all four of these examiners estimated fetal weight more accurately than E3 did, the untrained ultrasound examiner. However, overall, there were no significant differences between the four examiners who used abdominal palpation. The analysis showed that fetal weight estimates made by ultrasound were significantly more accurate than those made using abdominal palpation, provided the ultrasound was done by a trained examiner.

▶ **Fig. 1** illustrates the density of distribution of the estimated fetal weights compared to the actual birth weights for both the ultrasound group and the palpation group.

Learning curve

A linear regression model was used to assess whether there was a learning curve for estimating fetal weight, especially when using



▶ **Fig. 1** Density of distribution of estimated fetal weight compared to real birth weight, comparison of ultrasound versus palpation. The graphs clearly show that the estimate weight using ultrasound (red line) was quite close to the actual birth weight after birth. In contrast, fetal weight estimated with abdominal palpation (green line) differed significantly from the actual birth weight.

palpation to estimate fetal weight. The analysis showed that fetal weight estimates became more accurate over time, except for those of examiners E3 and E6. However, this relationship was not significant, and this study does therefore not provide evidence of a learning curve.

Influence of BMI and gestational age on fetal weight estimation

Linear regression analysis showed that maternal BMI and gestational age significantly reduced the accuracy of the fetal weight estimates. Both higher maternal BMI and greater gestational age increased the difference between estimated fetal weight and actual birth weight, meaning that the higher the maternal BMI or the more advanced the gestational age, the more difficult it was to accurately estimate fetal weight. Regression analysis carried out on the measured differences for each examiner showed that higher maternal BMI significantly reduced the accuracy of the weight estimates made by examiners E1, E4, E5 and E7. In contrast, greater gestational age reduced the accuracy of the estimates made by E2, E4 and E5.

Estimating the upper and lower extremes of weight

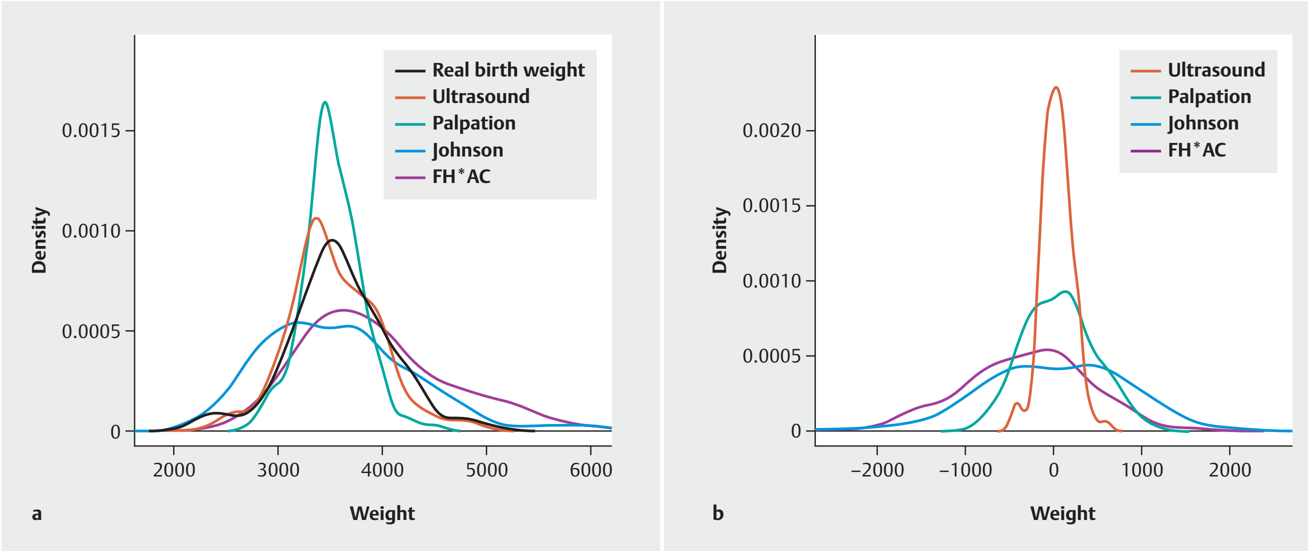
Analysis also showed a higher deviation between estimated weight and actual weight for the extremes of fetal weight, i.e. very low and very high fetal weight. Examiner E1 achieved the lowest mean square error (MSE), followed by examiner E2. E1 was quite accurate at estimating both higher weights (MSE = 62.46) and lower weights (MSE = 51.92). E2 estimated higher weights (MSE = 194.49) less accurately, underestimating them more, and E2's estimates of lower weights (MSE = 130.35) also deviated more from the actual birth weights. Examiners E3, E4, E5, E6 and E7 made nearly identical estimates, consistently underestimating higher weights (MSE = 493.67, 506.06, 416.49, 529.13, 456.99) and usually overestimating lower weights (MSE = 242.95, 477.72, 336.71, 365.37, 298.80). The results also showed that when ultrasound was carried out by trained examiners, estimated fetal weights at both the upper and lower extremes were more accurate than with abdominal palpation.

Comparison of all four methods

Mean weights were estimated quite accurately with all methods except for Insler and Bernstein's formula. All methods resulted in significant deviations in estimated weights for fetuses with extreme birth weights, although ultrasound achieved the highest accuracy, as indicated by the fact that the mean square error and the Kullback-Leibler divergence (KL) were the lowest for this method (MSE = 31, KL = 1.23). The highest deviation from the actual birth weights resulted from using Johnson's method (MSE = 650, KL = 25.19) and Insler and Bernstein's formula (MSE = 814, KL = 22.12). The MSE for palpation was 162 and KL was 6.27. ▶ **Fig. 2** shows the density of distribution and the den-

▶ **Table 2** Descriptive statistics and Kullback-Leibler divergence for estimated and real birth weights; comparison of examiners 1–7.

Examiner	Min	25 %	Median	Mean	75 %	Max	Standard deviation	Mean square error	Kullback-Leibler divergence
Real birth weight	2200	3298	3565	3576	3881	5050	485	–	–
E1	2350	3295	3490	3527	3810	4890	1535	3.14	1.22
E2	2894	3312	3582	3560	3782	4857	1489	8.10	3.18.
E3	2500	3310	3565	3590	3794	5592	1663	21.64	8.07
E4	2800	3400	3500	3554	3700	4600	1440	20.24	7.89
E5	2700	3400	3525	3548	3740	4500	1444	15.58	6.09
E6	2780	3350	3500	3524	3680	4320	1380	18.46	7.33
E7	2750	3358	3500	3509	3700	4500	1380	16.23	6.22



▶ **Fig. 2** Density distribution (**a**) and density of difference (**b**) of estimated fetal weight compared to actual birth weight for all four methods. The left graphs clearly show that the weight estimated with ultrasound (red line) was very close to the actual birth weight after birth (black line). In contrast, estimated fetal weight using abdominal palpation (green line), Johnson's method (blue line) or Insler and Bernstein's formula (pink line) clearly differed from the actual birth weight. The graphs on the right side show that the difference between estimated and actual weight was smallest when using ultrasound. Variations between estimated and actual weight were greater using any of the other three methods.

▶ **Table 3** Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for each method.

Method	Sensitivity[1]	Specificity[1]	PPV[1]	NPV[1]	Sensitivity[2]	Specificity[2]	PPV[2]	NPV[2]
Ultrasound	68.00	97.08	89.47	89.26	75.82	90.88	82.14	78.64
Palpation	20.00	94.33	57.89	75.14	35.42	76.00	58.62	55.07
Johnson's method	50.00	52.03	28.28	73.33	64.65	32.38	47.41	49.78
Insler and Bernstein's formula (FH * AC)	42.86	54.73	26.37	71.68	67.68	35.05	51.15	56.16

[1] Cut-off fetal weight to actual weight up to 1 000 g. [2] Cut-off fetal weight to actual weight up to 500 g.

sity of differences between the estimated fetal weights and the actual birth weights for all four methods. The graphs clearly show that the difference was lowest – and the accuracy was therefore highest – with ultrasound.

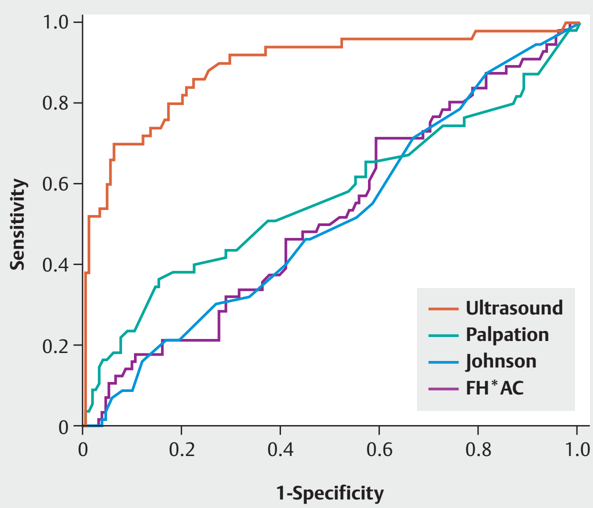
With regard to sensitivity, specificity, PPV and NPV, ultrasound was found to be the most accurate of all four methods, irrespective of the cut-off weight variation used. The details are given in ▶ **Table 3**.

▶ **Fig. 3** shows the ROC curves for all four methods used. An accurate method for estimating fetal weights should result in an ROC curve that rises horizontally and then continues in parallel to the x-axis. In ▶ **Fig. 3**, only fetal weight estimates made using ultrasound created the ideal curve. The ROC curves for Johnson's method and Insler and Bernstein's formula were almost diagonal, indicating a random process. The ROC curve for abdominal palpation showed a sharp rise but then became almost diagonal.

Discussion

Accurate fetal weight estimation is very important because it is used to make decisions about the mode of delivery and the timing of labor induction. The results of the present study clearly show that ultrasound is more accurate in estimating fetal weight than abdominal palpation.

Previous studies have come to different conclusions, with some studies concluding that fetal weight estimates made by ultrasonography were the most accurate [12, 14–18], other studies reporting that the accuracy of fetal weight estimation by palpation was poor [19], and others concluding that estimates made based on palpation were as accurate as or even more accurate than ultrasound [13, 20–25]. However, fetal weight estimates made at term have been reported to be fairly inaccurate with both methods, particularly when estimating the weight of macrosomic fetuses [1, 26]. The different approaches used in these studies,



▶ **Fig. 3** Predictive performance (ROC curves) for the four methods. An accurate method for estimating fetal weights should result in a ROC curve that rises horizontally and then continues in parallel to the x-axis. Only fetal weight estimated using ultrasound (red line) resulted in the ideal curve. The ROC curves for Johnson's method (blue line) and Insler and Bernstein's formula (pink line) are almost diagonal, indicating a random process. The ROC curve for abdominal palpation (green line) initially rose sharply but then became almost diagonal.

the time between estimating the weight and the actual birth and differences in the examiners' skill could explain the differences in the results published so far.

Other studies of sonographic fetal weight estimation have observed that accuracy depended on the formula used and that estimates made between four and seven days prior to delivery were the most accurate [27–29]. The present study only included women who gave birth within five days after the fetal weight was estimated. The mean interval between fetal weight estimation and delivery was 2 days (± 1.7), which is quite short compared with the times reported in previous studies. In addition, it should be noted that some studies did not calculate fetal weight using Hadlock's formula; however, a systematic review showed that Hadlock's formula is the formula most consistently used in normal clinical populations and for patients in labor [30].

The results of the present study and of more recent studies show that ultrasound was better at estimating fetal weight [5, 18, 31–36]. The present study also showed that ultrasound training increases the accuracy of fetal weight estimates, with the most accurate estimates made by an ultrasound professional (E1), followed by a trained ultrasound examiner (E2), while the results calculated by an inexperienced and untrained ultrasound examiner (E3) were less accurate than those of either E1 and E2 and even less accurate than those of the examiners who used abdominal palpation. Other studies have shown that advanced professional training improves the accuracy of sonographic fetal weight estimates [7, 25, 37], a finding that has been confirmed by this study. A structured ultrasound training program and the assessment of fetal weight by biometry should be routinely incorporated in the training of obstetric residents.

Of the examiners who used abdominal palpation, the experienced obstetrician (E4) and the experienced midwife (E7) estimated fetal weights more accurately than the other two examiners. This confirms the results of a previous study which showed that senior residents estimated fetal weight more accurately than junior residents did [24]. Weight estimates using abdominal palpation are simple and fast and do not require any special equipment. With this method, skills are obtained through experience and are based on a comparison of previous approximations and the actual outcomes. One could assume that professionals who trained when ultrasound technology was less sophisticated and was used less commonly in daily clinical routines or whose training mainly focused on manual examinations would perform much better when using abdominal palpation. Leopold's maneuvers are still being taught but are rarely used in daily clinical practice, as the use of ultrasound is now routine in developed countries. In the present study, there were hardly any differences between the examiners who used abdominal palpation to estimate fetal weight. Previous studies found that the ability to estimate fetal weight did not improve with professional experience. Those studies showed that the examiners' experience and their obstetrical training did not significantly affect the accuracy of their clinical fetal weight estimates [19, 38]. Although data from our study shows that fetal weight estimates became more accurate over time, with the exception of examiners E3 and E6, the improvement did not reach statistical significance, and the study does not provide evidence of a learning curve. This was quite surprising, as fetal weight estimates based on abdominal palpation rely on clinical experience and knowledge of the accuracy of past estimates. We therefore expected to find a learning effect among the examiners who used this method.

The data in the present study showed that the examiners' estimates were predominately average, seldom extremely high or low. One previous study noted that experienced midwives assessed fetal weights of more than 4000 g more accurately than obstetricians did. The authors assumed that the estimates of obstetricians tended to be conservative because fetal macrosomia could mandate a delivery by cesarean section [38]. However, in the present study, the weight estimates were not made during appointments, considerably reducing the possibility of this kind of bias. Nevertheless, there was apparently a reluctance to estimate very high or very low birth weights.

Analysis of the estimated weight at the upper and lower extremes confirms the low accuracy of fetal weight estimates for extremely large or extremely small babies. The weights of heavier fetuses were greatly underestimated, while the weights of fetuses subsequently found to be of low birth weight were greatly overestimated. There seemed to be a tendency to aim for a fetal weight within normal percentiles, particularly when examiners used abdominal palpation. Previous studies have demonstrated a tendency to underestimate or overestimate, particularly lower and higher fetal weight, with both ultrasound and clinical examination [12, 19, 38–41]. The results of this study and previous studies [12] show that ultrasound estimates were more accurate than abdominal palpation for both the upper and lower ranges of birth weight percentiles. In the present study, the rates of both under- and overestimation were significantly higher for examiners who used abdominal palpation.

This study also showed that fetal weight estimates were less accurate in women with higher BMI. Previous studies have also reported a relationship between higher maternal BMI and less accurate estimates of fetal weight [42, 43]. Although this relationship appears to be plausible, in the present study, it was significant for only five of the seven examiners (E1, E2, E4, E5 and E7) and could not be verified for the other two examiners (E3, E6). However, not all studies have supported this proposed relationship between higher maternal BMI and less accurate estimates of fetal weight [44–46]. This could be due primarily to methodological differences or small sample sizes. The present study found a significant relationship between examiners' experience and less accurate fetal weight estimates when the mother had a high BMI. Generally, variations in estimated fetal weights were higher for examiners E3 and E6, and maternal BMI did not seem to affect the statistical analysis of their estimates. The results of one recent study support this assessment, demonstrating that maternal BMI did not decrease the accuracy of fetal weight estimates made by abdominal palpation, as it was inaccurate irrespective of maternal BMI [19].

The present study found that the impact of gestational age differed significantly between examiners E2, E4 and E5, all of whom estimated fetal weights less accurately at advanced gestational ages. In fact, as fetuses become more flexed near to term and presented parts are more readily engaged, it is plausible that gestational age could affect fetal weight estimates made using ultrasound. Another recent study observed a significant trend toward inaccurate clinical fetal weight estimates made by palpation at an advanced gestational age [19]. However, as the differences were small and were not reported for all examiners, the effect might be marginal.

Most of the studies that compared fetal weight estimation by ultrasound, abdominal palpation, Johnson's method and Insler and Bernstein's formula reported similar values for all methods [13, 18, 24, 25, 47, 48]. However, our study clearly demonstrated a better accuracy when fetal weight was estimated by ultrasound, as shown in the ROC curves (▶ **Fig. 3**) and the calculated sensitivities, specificities, PPVs and NPVs (▶ **Table 3**). Palpation and Johnson's method may provide alternatives to ultrasound in countries which lack advanced ultrasound technology [34, 49–51]. As Johnson's method only requires fundal height measurement in cm and an evaluation of the station level to complete the calculation, it is proposed as a good alternative for estimating fetal weight in less developed countries. However, the results of the present study and other studies demonstrate that sonographic examination is more accurate in assessing fetal growth and estimating fetal weight [13, 47, 48].

In conclusion, there is an overall agreement that the most reliable and accurate method for fetal weight estimation should be used, where possible. The results of the present study indicate that if ultrasound technology and expertise are available, the focus should be on providing ultrasound training for fetal weight estimation, as most recent studies agree that ultrasound is the most accurate method. It should also be noted that, in recent studies, the accuracy of fetal weight estimated using ultrasound was higher than in studies conducted in the 1990s or even earlier. Ultrasound is now more accurate, as ultrasound technology has greatly improved in recent years.

To improve the reliability of ultrasound, future studies are needed to develop new formulae to predict fetal weight more accurately and identify the threshold at which combining clinical fetal weight estimates with sonographic estimates could be useful to identify fetal macrosomia. Until such results are available, it would be advisable to focus on providing obstetricians with structured ultrasound training and to use ultrasound to assess fetal weight at term.

Acknowledgements

We would like to thank all of the women who participated in the study. We also would like to thank Prof. Sibbertsen and Dr. Bertram from the Statistical Institute of the University of Hanover for providing us with statistical advice and for carrying out the statistical analysis.

Funding

This study received no separate funding.

Ethics

This study was approved by the local Ethics Committee of Hanover Medical School (No: 1286-2011).

Conflict of Interest

The authors declare no conflict of interest.

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