

# Impact of Ultrasound Training and Experience on Accuracy regarding Fetal Weight Estimation at Term Creative Education

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## Abstract

The focus of this prospective study was to evaluate whether experience and level of training improves and influences the accuracy of fetal weight prediction by ultrasound. At term fetal weight is an important component for decisions concerning delivery mode and timing of labor induction. In 204 singleton pregnancies at term fetal weight estimation by ultrasound was performed by three examiners of different levels of professional experience and education. Examiner 1 was a specialist experienced consultant. Examiner 2 was a resident in the 2<sup>nd</sup> year, who had a structured supervised ultrasound training for six month and examiner 3 was a resident in the 2<sup>nd</sup> year, who received no structured supervised ultrasound training. The results of this study clearly showed that experienced ultrasound examiners estimate fetal weights more accurately than unexperienced examiners. Additionally, there is an impact of the level of resident's training on the results. The professional, most experienced examiner 1 estimated fetal weight the most precise, followed by the trained examiner 2, who achieved more accurate weight estimation than examiner 3. We could show that an intensive supervised training of at least six months is adequate to improve the accuracy of weight estimation significantly. Obstetric ultrasound is getting increasingly important in daily maternal-fetal medicine. Thus, it is essential not only to develop effective training curricula for obstetric and gynecological residents, but also to implement a comprehensive supervised ultrasound training. The results could demonstrate that it seems justified to spent time and resources on residents training, in order to meet the increasing demands of modern obstetric medicine.

## Keywords

Ultrasound, Training, Teaching, Supervision, Obstetrics, Gynecology

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## 1. Introduction

Fetal weight estimation during pregnancy is an important component in prenatal and intrapartum care. At the end of the pregnancy fetal weight estimation gains in importance regarding birth planning. Accurate estimation of fetal weight is essential as delivery of a macrosomic fetus is associated with for example prolonged labor and traumatic delivery such as shoulder dystocia, brachial plexus injuries and intrapartum asphyxia, as well as maternal risks that include birth canal injuries and postpartum hemorrhage (Chauhan et al., 1998; Boulet et al., 2003; Ugwa et al., 2015; Husslein et al., 2012). On the other hand, it is necessary to identify a growth restricted fetus to determine control interval and finally the time of delivery, to minimize perinatal risks such as intrauterine fetal death (Bernstein et al., 2000). Therefore, strategies for intrapartum management may obviously be influenced by fetal weight estimation and consequently it is important to perform a most accurate fetal weight estimation.

Nowadays the main and most used method to determine fetal weight estimation is via ultrasound. Ultrasound is a routine tool in prenatal and obstetric care. The most common used formula for fetal weight estimation is Hadlock, which contains fetal head circumference, abdominal circumference and femur length. Although fetal weight estimation by ultrasound is the most accurate method, fetal weight estimation via ultrasound shows measurement variations to real birth weight, which can vary up to  $\pm 500$  g at term or near term. In addition to the variations due to ultrasound as a method there also are variations in fetal weight estimation between different examiners (Hadlock et al., 1984; Chien et al., 2000; Predanic et al., 2002; Nahum & Stanislaw, 2003; Chauhan et al., 2005; Dudley, 2005).

Ultrasound is one of the most important and most used diagnostic tools in gynecological, obstetrical and prenatal care. Despite of its diagnostic value, training in ultrasound during the residency period is often still underrepresented as a standard rotation.

The aim of this study was to compare fetal weight estimation by ultrasound with the actual birth weight. The focus of this analysis was on the role of experience and level of training on ultrasound accuracy of fetal weight prediction. Additionally, accuracy in fetal weight prediction near and at term by ultrasound technique was evaluated and parameters that may affect the prediction.

## 2. Methods

This prospective study took place over a one-year period at the department of Gynecology and Obstetrics at Hanover Medical School.

Women with a singleton pregnancy between 37 gestational weeks and 12 days postterm with a planned normal vaginal delivery or an elective/planned caesarean section were asked to participate in the study.

Exclusion criteria were multiple pregnancies, fetal anomalies, all pregnancies less than 37 weeks of gestation and intrauterine fetal deaths. Women, who agreed to participate in this study, but delivered more than 5 days after the pre-

diction of fetal estimated weight, were also excluded from analysis.

After obtaining informed consent from the participants, fetal weight estimation was performed by ultrasound. The fetal weight was calculated after measuring femur length, biparietal diameter and frontooccipital diameter for calculating head circumference as well as abdominal transverse diameters for calculating abdominal circumference always using the same high end ultrasound device (GE, Voluson E, 3.5 MHz abdominal transducer). The measurements were entered into the datasoftware (viewpoint database) and fetal weight was calculated using Hadlock's formula.

Fetal weight examination was performed by three different examiners. The first examiner (E1) was an ultrasound specialist with more than 10 years of professional experience. The second (E2) and third examiner (E3) were residents. Examiner two (E2) was intensively trained in ultrasound skills for 6 month by examiner one, whereas examiner three (E3) was taught the basic measuring planes within 10 days and gained skills by watching prior to this. Both residents were at their second year of residency (out of a 5-year program). None of the examiners had knowledge about the other examiners' estimation of fetal weight or the hospital notes. Only details about gestational age and parity were given to the examiners. Maternal demographic characteristics as maternal age, gestational age, BMI and parity were recorded. Furthermore, neonatal details as birth weight and delivery date were documented. After delivery, all newborns were weighed within an hour after birth using the same weighing scale (Seca type), which was calibrated regularly on an automatically basis.

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

### Statistical Analysis

The statistical analysis was carried out in collaboration with the Institute of Statistics of the University of Hanover. Demographic details are given as either mean or percentage. Depending on the variables, statistical analysis was performed by using the statistic program R (<http://www.cran.r-project.org>).

To compare the estimated fetal weight with the real birth weight, minimum, first quartile, median, arithmetic medium, third quartile, maximum, standard deviation and the mean square error was calculated for each examiner. Mean square error is a measure which provides a comparison of the prediction of the estimated weight with regard to the real birth weight. Additionally, the Kullback-Leibler-divergence was used to demonstrate how close the estimated fetal weight was predicted compared to the real birth weight. Diebold-Mariano-Test was used to determine the accuracy of fetal weight prediction between the examiners. Based on the difference between estimated and real weight Goldfeld-Quandt-Test was used to calculate the variance of measured differences between the examiners. A possible learning effect and potential influencing factors in fetal weight estimation were analyzed by Pearson correlation and linear regression model. Statistical significance is achieved if  $p < 0.05$ .

### 3. Results

204 women were included in the analysis after signing informed consent. The demographic details of the study population are demonstrated in **Table 1**.

First, the estimated weight was compared with the real birth weight in between the three examiners (E1-3). The descriptive statistics of the estimated fetal weight to the real birth weight and the Kullback-Leibler divergence is demonstrated in **Table 2**. While the median birth weight, the first quartile and the third quartile is satisfactorily predicted by all examiners, there are significant deviations in fetuses with extreme birth weights. Only the ultrasound professional (E1) came close to the minimum and maximum birth weight. The standard deviation is always higher than the real fetal weight. Most important for the quality assessment is the mean square error between the estimated and real weight. The mean square error is the lowest with examiner 1 (3.14), followed by examiner 2 (8.10). Examiner 3 has the highest predictive error (21.68).

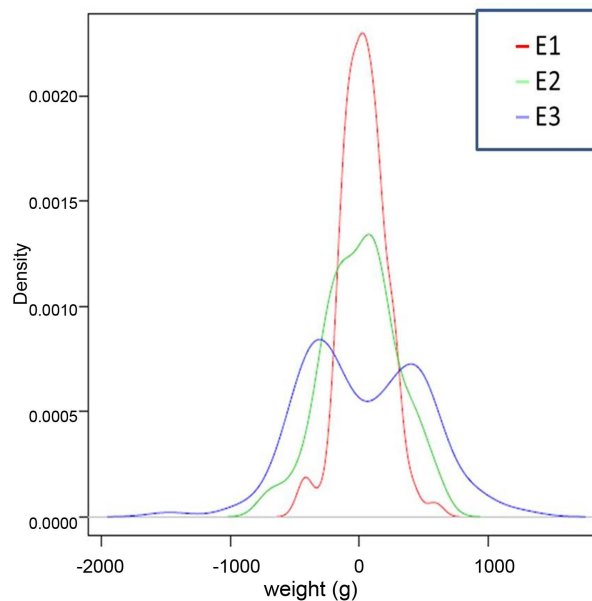
Kullback-Leibler-divergence shows the accuracy of fetal weight estimation compared to the real birth weight. The smaller the value, the closer are the measurements to the real fetal weight. The data of Kullback-Leibler-divergence match with the results of the predictive error. Fetal weight estimation was best performed by E1, followed by E2.

**Table 1.** Demographics details.

Demographics details N = 204	
<b>Maternal Characteristics</b>	
Maternal age (years) median (range)	31.6 (16.0 - 45.0)
Gestational weeks median (range)	39.7 (37.0 - 42.0)
BMI (kg/m <sup>2</sup> ) 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-Adipositas (BMI > 30.0) N (%) mean (range)	101 (49.5%) 34.9 (30.0 - 53.0)
<b>Ethnicity</b>	
White N (%)	199 (97.4%)
Black N (%)	3 (1.5%)
Asian N (%)	2 (0.9%)
Primiparous N (%)	113 (55.4%)
Multiparous N (%)	92 (45.1%)
<b>Neonatal Characteristics</b>	
Birth weight median (range)	3575.9 (2200 - 5050)
Neonatal length median (range)	52.8 (46 - 59)
Neonatal head circumference median (range)	35.3 (31.5 - 39.0)
Female gender N (%)	94 (46.1%)
Male gender N (%)	110 (53.9%)

**Table 2.** Descriptive statistic and Kullback-Leibler divergence for estimated and real birth weight.

	Min	25%	Median	average	75%	Max	Standard deviation	mean square error	Kullback-Leibler divergence
<b>Real birth weight</b>	2200	3298	3565	3576	3881	5050	920	-	-
<b>E1</b>	2350	3295	3490	3527	3810	4890	1535	3.14	1.22
<b>E2</b>	2894	3312	3582	3560	3782	4857	1489	8.10	3.18
<b>E3</b>	2500	3310	3565	3590	3794	5592	1663	21.64	8.07

**Figure 1.** Density of difference of actual birth weight and estimated fetal weight.

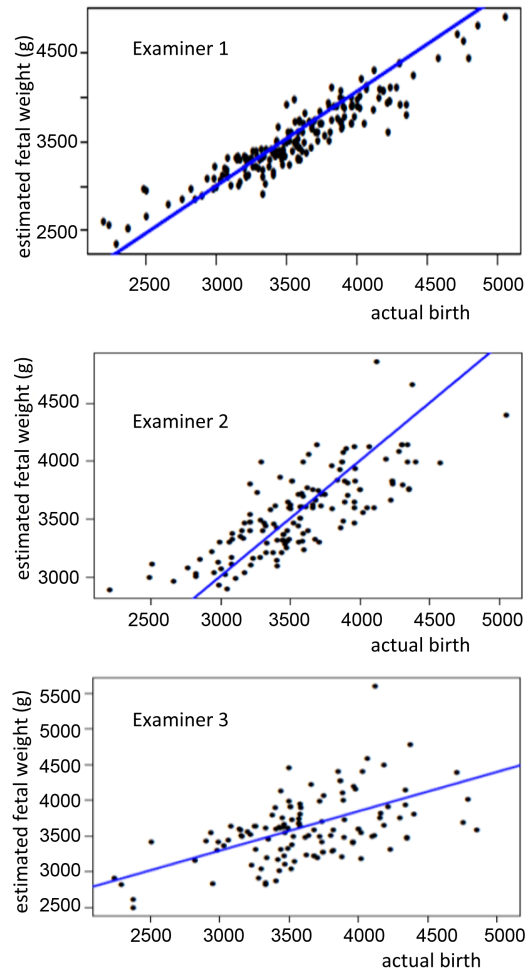
The distribution of deviation of predicted fetal weight compared to the real-birth weight is demonstrated in **Figure 1**, which clearly displays that the difference is the smallest for examiner 1.

The difference between the estimated birth weight and the real birth weight in grams is shown in **Table 3**. The best results are seen for the ultrasound professional (E1) as reflected in the smallest standard deviation.

Examiner 1 is significantly ( $p = 0.001$ ) more accurate in weight estimation than examiner 2 and examiner 3, followed by examiner 2. The scatterplot (**Figure 2**) displays the correlation of estimated fetal weight to actual neonatal birth weight for each examiner.

To assess whether there is a learning curve in fetal weight estimation, a linear regression model was established. The analysis demonstrates that fetal weight estimation was getting more precise, except for examiner E3. Though no significance was achieved, therefore we could not prove a learning curve in our study.

Furthermore, linear regression analysis revealed maternal BMI and gestational



**Figure 2.** Scatterplots showing the correlation of estimated fetal weight to actual birth weight for each examiner separately.

**Table 3.** Descriptive statistic for predicted fetal weight, given as difference treme for each examiner to the real birth weight in gram (g).

	Min	25%	Median	average	75%	Max	Standard deviation
<b>E1</b>	-483	-78.5	31.0	35.87	141.5	620	174.06
<b>E2</b>	-737	-181.5	29.0	9.93	195.5	654	285.40
<b>E3</b>	-1472	-331.5	-49.0	29.46	403.0	1273	466.19

week as influencing factors on the precision of fetal weight estimation. A greater BMI as well as an advanced gestational age increases the deviation of estimated fetal weight to real birth weight. Therefore, an accurate estimation of fetal weight is more difficult to achieve the higher the BMI and the more advanced the gestational age.

When applying the regression analysis on the measured deviation of each examiner, the results revealed that an increased BMI influences the accuracy of weight estimation of examiner 1 significantly. Whereas advanced gestational age

caused a greater inaccuracy in weight estimation of examiner 2 and examiner 3.

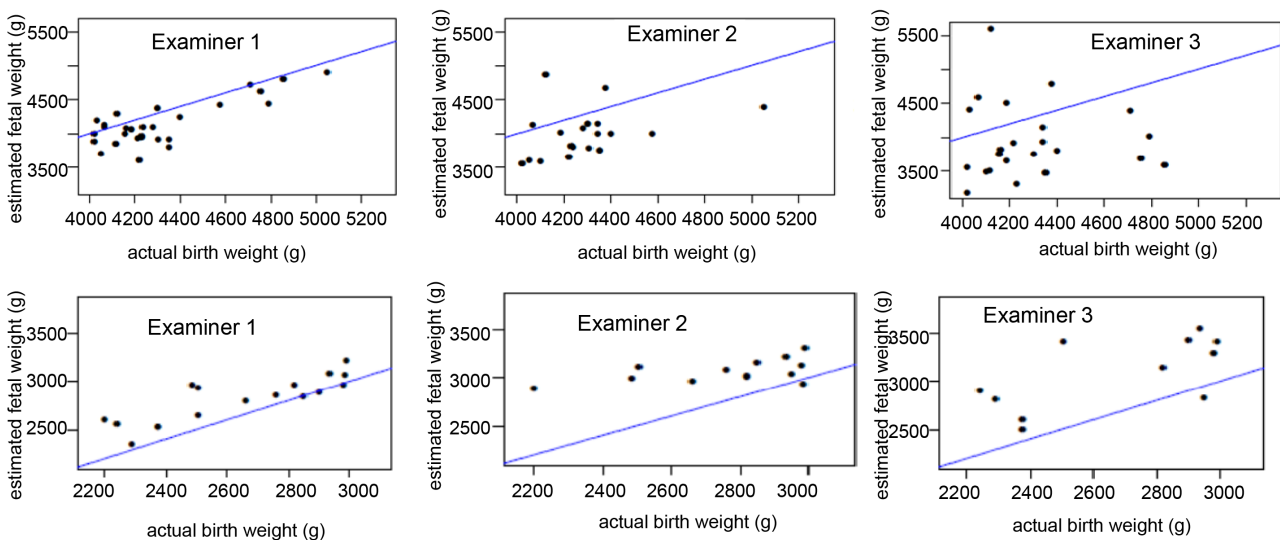
The analysis revealed a higher deviation of estimated to real weight particularly at both extremes of fetal weight, in very low or very high weights. Therefore, further analysis was conducted investigating only these extremes of fetal weight. Only birth weights lower than 3000 g and greater than 4000 g were considered for further analysis. The mean square error for each extreme was calculated and is provided in **Table 4**. Examiner 1 achieved the lowest mean square error, followed by examiner 2. Estimation of high weights as well as low weights were highly accurate for Examiner 1. Examiner 2 shows a diminishing accuracy for heavier weights and therefore underestimated the real weight. Regarding the lower extreme, estimated fetal weight of examiner 2 shows a higher divergence towards the actual birth weight compared to examiner 1. Examiner 3 consequently underestimated the heavier weights and usually overestimated the lower weights. The results show also at the upper and lower extreme of weight a significantly ( $p < 0.001$ ) better fetal weight estimation by trained and experienced examiners. **Figure 3** is demonstrating the estimated fetal weight compared to the actual birth weight at the upper and lower extreme for examiner 1 to 3.

#### 4. Discussion

Basic practical training for both gynecological and obstetric ultrasound remains

**Table 4.** Mean square error at upper and lower extreme for each examiner to the real birth weight in gram (g).

Examiner	mean square error-upper extreme (>4000g)	mean square error-lower extreme (<3000g)
Examiner 1	62.46	51.92
Examiner 2	194.49	130.35
Examiner 3	493.67	242.95



**Figure 3.** Estimated fetal weight compared to the actual birth weight at the upper and lower extreme for examiner 1 to 3.

a challenge. Limitations of an effective practical teaching and training are personal instructions and the possibility of supervising the resident during examination, which is essential and mandatory for the resident, in order to learn scanning, to learn how to establish the correct ultrasound planes, how to move the probe and which landmarks are important.

Teaching vaginal ultrasonography is even more challenging as the vaginal ultrasound examination is by most women considered uncomfortable and this rather shame inflicted circumstance causes an uncomfortable situation for a young doctor which hampers an effective learning atmosphere.

However, ultrasound is considered to be one of the main medical diagnostic tools, especially in gynecology and obstetrics. Therefore, it is surprising that a lack of understanding of the importance of a structured practical ultrasound training as a basic tool during residency training is highly necessary.

Performing a good ultrasound examination has an essential impact in the clinical assessment. As described above, fetal weight estimation is important concerning further management with regard to delivery mode and timing of induction of labor.

The results of this study clearly show that experienced ultrasound examiners estimate fetal weights more accurately than unexperienced examiners. Additionally, there is an impact of the level of resident's training on the results. The results of the present study demonstrate that ultrasound training increases the accuracy of fetal weight estimation. The professional, most experienced examiner 1 estimated fetal weight the most precise, followed by the trained examiner 2, who achieved more accurate weight estimation than examiner 3, who received no supervised ultrasound training.

These results confirm previous study results, showing that the accuracy of fetal weight estimation was better with a higher level of physicians' experience (Barel et al., 2013; Bolanca et al., 2005; Baum et al., 2002).

We were able to show that an intensive supervised training of at least six months is adequate to improve the accuracy of weight estimation significantly. Another previous study could also demonstrate an improvement of accuracy in fetal weight after advanced professional ultrasound training, achieving the best results when training lasted 24 months (Predanic et al., 2002).

The present study shows that fetal weight estimates were less accurate in women with higher BMI. This was already demonstrated in previous studies (Fox et al., 2009; Houzé de l'Aulnoit et al., 2009; Field et al., 1995). Although this relationship of high BMI and less accurate ultrasound examination appears to be reasonable, it was significant only for examiner E1 and E2 and could not be demonstrate for examiner E3 in the present study. However, it must be considered that examiner's 3 estimations varied in such an extent that the BMI apparently did not have an influence on the accuracy of fetal weight estimation. However, a few studies have not supported this relationship between higher maternal BMI and less accurate estimates of fetal weight (Farrell et al., 2002; Heer et



al., 2008).

In addition, the present study demonstrates that the impact of gestational age on fetal weight estimation differs significantly among examiners E2 and E3, who estimated fetal weights the least accurate with advanced gestational ages. In fact, as fetuses become more flexed at term and presented fetal parts can be readily engaged, it is plausible that gestational age affects fetal weight estimates via ultrasound, especially in inexperienced examiners. This underlines the importance and necessity of a guided and supervised ultrasound training, in which pitfalls and approaches for difficult situations can be addressed.

The results of this study and previous ones (Bolanca et al., 2005; Colman et al., 2006) reveal not only variations due to ultrasound as a method in fetal weight estimation, but also variations in fetal weight estimation due to different examiners. They demonstrate that accuracy in fetal weight estimation positively correlates with the level of the physician's experience.

In general, the positive effect of ultrasonographic training within an organized module is also shown for other objects under study, for example, the accuracy of cervical length measurements (Vahanian et al., 2016). Van Holsbeke *et al.* have demonstrated that interpretation of ultrasound images improves with increasing levels of experience. Less experienced examiners were less accurate in pattern recognition of static ultrasound images. The results of this study (Van Holsbeke et al., 2010) illustrate that both experience and training matter, even when reading static images. This implies that learning from books only and creating the correct ultrasound image on one's own is insufficient.

Several investigations, which assessed theoretical and practical aspects of ultrasound training in obstetrics and gynecology, have already demonstrated the relevance and effectiveness of ultrasound training (Alcázar et al., 2013; Sidhu et al., 2012; Tutschek et al., 2012; Salvesen et al., 2010; Calhoun & Hume, 2000). Other studies proved, in addition to integrated ultrasound curricula, that further complementary teaching methods like hands-on courses, workshops and ultrasound simulators can significantly improve ultrasound skills (Nitsche & Brost, 2013; Staboulidou et al., 2010; Pascual et al., 2016; Macedonia et al., 2003).

Although, many efforts have been made to establish ultrasound programs by different international institutions, such as the American Congress of Obstetrics and Gynecology (ACOG, 2013), the European Board and College of Obstetrics and Gynecology (EBCOG, 2005), the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB, 2005) and the Royal College of Obstetrics and Gynaecology (RCOG) (Lees & Hinshaw, 2010).

However, despite the willingness to integrate those ultrasound programs in the curricula of the resident's education, they are hardly implemented in daily clinical routine. Traditionally sonographic skills are still gained almost entirely from exposure to ultrasound in the routine clinical setting on a "see one, do one" basis (Nitsche & Brost, 2013; Lee et al., 2004).

Our results indicate that if ultrasound technology and expertise are available,

ultrasound training should be a major focus in the education of residents in Obstetrics and Gynecology.

## 5. Conclusion

In conclusion, the available studies show that an ultrasound education program for residents is worthwhile, because an accurately performed ultrasound is essential for attaining the correct diagnosis. For our study in fetal weight prediction, a precisely performed ultrasound examination has a great impact on counselling the parents with regard to the mode of delivery in order to provide a safer labor for both, mother and baby.

Obstetric ultrasound is getting increasingly important in daily materno-fetal medicine. Thus, it is essential to not only develop effective training curricula for obstetric and gynecological residents on paper, but also to implement a comprehensive and supervised ultrasound training into clinical practice. Our results as well as previous studies demonstrate that it is justified to spend time and resources on residents' ultrasound training, in order to meet the increasing demands of modern obstetric medicine.

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## Conflict of Interest

The authors declare no conflict of interest.

## Ethics

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

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