International Journal of Biomedicine 12(1) (2022) 43-48
http://dx.doi.org/10.21103/Article12(1)_OA5

INTERNATIONAL JOURNAL OF BIOMEDICINE

ORIGINAL ARTICLE

Obstetrics and Gynecology

Predicting Fetal Weight by Ultrasonography Using Hadlock Formula 1

Mohamed Adam*

Department of Radiological Sciences, College of Applied Medical Sciences, King Khalid University, Abha, Kingdom of Saudi Arabia

Abstract

Background: Accurate fetal weight estimations by ultrasound are essential in determining the method and time of delivery. Hadlock formulas have been proposed for providing fetal weight estimations, including Hadlock 1, Hadlock 2, Hadlock 3, and Hadlock 4. Because none of the formulas have been verified, it is unknown which one can be best applied to the Saudi population. This study aims to determine the validity of the Hadlock formula 1 for EFW by using ultrasonography.

Methods and Results: The study sample was 198 women with singleton pregnancies with gestational ages between 37 and 41 weeks, admitted for ultrasound evaluation. The FW was estimated by ultrasound using the Hadlock formula 1. After the ultrasound EFW, we followed up with the pregnant women within three days (from ultrasound scan to delivery date) and measured actual BW. The study found that the mean BW was 3179±387 g, ranging from 2500 g to 4290 g. The mean ultrasound EFW was 3055±378 g, ranging from 2500 g to 4100 g. The difference between the mean ultrasound EFW and actual BW (123.81±107.95 g) was significant (P=0.0014).The formula for prediction of birth weight is BW=0.9831EFW by ultrasound±175.55g. In addition, a significantly positive correlation was found between ultrasound EFW and BW (r=0.961, P=0.000).

Conclusion: The significantly positive correlation between EFW by ultrasound and BW indicates that the Hadlock formula 1 for predicting FW is accurate, valid, and effective in the research environment.(**International Journal of Biomedicine. 2022;12(1):43-48.**)

Key Words: birth weight • Hadlock formula • estimated fetal weight • ultrasonography

For citation: Adam M. Predicting Fetal Weight by Ultrasonography Using Hadlock Formula 1. International Journal of Biomedicine. 2022;12(1):43-48. doi:10.21103/Article12(1)_OA5

Abbreviations

AC, abdominal circumference; **BW**, birth weight; **BPD**, biparietal diameter; **EFW**, estimated fetal weight; **FL**, femur length; **FW**, fetal weight; **HC**, head circumference.

Introduction

Birth weight (BW) is an important determinant of newborn survival.[1,2] Therefore, weight assessment is an essential aspect of antenatal care utilized in labor, delivery, growth monitoring, and managing high-risk pregnancies.[1] An accurate estimation of fetal weight (FW) is beneficial in late pregnancy because it helps obstetricians with providing labor management and determining the mode of delivery. Because of the possible difficulties from low and high fetal BW during labor and the puerperium, it is often necessary to accurately evaluate prenatal FW. Intrauterine growth restriction, preterm delivery or both are responsible for the increased perinatal morbidity and mortality associated with low BW. Shoulder dystocia, bone injuries, brachial plexus injury, and intrapartum hypoxia are among the potential problems of vaginal delivery for overly large fetuses. Thus, there is a significant concern for the mother's health, including her birth canal and pelvic floor.[3,4]

Leopold techniques and ultrasonography are the most common methods for predicting FW.[5,6] However, clinical EFW has been demonstrated to predict BW accurately. Baum et al.[7] found no significant difference between clinical and

***Corresponding Author:** Dr. Mohamed Adam. College of Applied Medical Sciences, King Khalid University, Abha, Aseer Region, Kingdom of Saudi Arabia. E-mail: o_maurie2006@yahoo.com*

sonographic EFW; 64% and 62.5% of the estimates were within 10% of the actual BW, respectively. In both term and postdate newborns, the clinical and ultrasound estimations of maternal EFW were the same. Clinical EFW, according to some experts, is more accurate than ultrasound EFW.[8] However, the accuracy of using several ultrasound parameters to estimate FW is receiving more attention; Shepard, Hadlock, Campbell S, and Nahum GG, among others, have developed several formulas and equations for predicting FW.[9-12] Ultrasound EFW is relatively accurate, with a 1%–5% margin of error. Although some researchers believe sonographic estimations are superior to clinical estimates, others have found that the two procedures provide equivalent levels of accuracy. This study aims to determine the validity of the Hadlock formula 1 for EFW by using ultrasonography.

Materials and Methods

This prospective, cross-sectional, nonintervention, comparative descriptive study was carried out over 36 months from June 2019 to June 2021 at the Obstetrics and Gynecology Hospital, El-mahala Aseer region, Abha.

The study sample was 198 women with singleton pregnancies with gestational ages between 37 and 41 weeks, admitted for ultrasound evaluation. The participants were randomly selected from a group of antenatal care with accurate menstrual dates. Pregnant women with medical conditions that might affect FW, multiple pregnancies or fetal chromosomal or congenital anomalies were excluded. The FW was estimated by ultrasound using the Hadlock formula 1, which was set into the ultrasound equipment by the radiology unit. After the ultrasound EFW, we followed up with the pregnant women within three days (from ultrasound scan to delivery date) and measured actual BW.

Index Tests

We approached women with singleton pregnancies and sought and received their informed consent to participate in this study. After that, the participants were initially given a routine sonographic evaluation, performed following the practice guidelines for the performance of obstetric ultrasound examinations of the American Institute of Ultrasound in Medicine (AIUM).[13] The scan was performed in a dimly lit room to minimize the screen's reflected artifact, with the participants in a supine position and a sonic coupling agent applied to their abdomen. Next, a simple sweep of the transducer was conducted up, down, and across their abdomen to get a rough sense of the uterine contents before focusing on specific areas of interest. The participants were closely observed to catch any agitation, shortness of breath or dizziness due to inferior vena cava compression by the gravid uterus. Participants who exhibited these symptoms were rolled onto their sides until these symptoms disappeared, after which they were moved back to the supine position, and the scan was completed. A based scan of gross anatomic abnormalities and maternal pelvis for masses was conducted after getting a rough sense of the fetus' position within the uterus, fetal heartbeat, placenta localization, liquor, and gestational age. After evaluating the pregnancy, the EFW was identified by measuring the femur length (FL), head circumference (HC), and abdominal circumference (AC) using internal electronic calibers. The results were presented in centimeters (cm).

Femur Length Measurement

FL was obtained from the longest longitudinal and coronal section of the femoral diaphysis. In the coronal plane, the lateral surface of the near side femur and the medial surface of the far side femur were imaged, while in a sagittal scan, the anterior or posterior surfaces of the femur were imaged depending on the direction of the sound beam with respect to the femur. In most cases, the iliac bone was used as a reference point, rotating the transducer until the longest FL was recognized. Next, the calipers were positioned, and the end-to-end length of the diaphysis was measured, excluding any ossified portion of the femoral neck, head, and distal or proximal epiphyses.

Abdominal Circumference Measurement

AC was obtained after determining the lie of the fetus and the orientation of the fetal spine's long axis. Next, the transducer was quickly rotated, and the image was frozen for AC measurement. From the true axial section of the fetus' upper abdomen at the level of the umbilical vein, left portal vein, and portal sinus confluence, the AC was measured using electronic calibers by tracing the outer edge of the fetal abdomen (skin/amniotic fluid interface).

Head Circumference Measurement

HC was measured on the same plane as biparietal diameter (BPD)—axial plane—that traverses the thalami and cavum septum pellucidum. The transducer must be perpendicular to the central axis of the head, and the hemispheres and calvaria should appear symmetric. In addition, the cerebellar hemispheres should not be in the image plane, or the probe will be too cauda and give an inaccurate size of the fetal head.

Statistical analysis was performed using the standard Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp). Continuous variables were presented as mean±standard deviation (SD). A probability value of $P<0.05$ was considered statistically significant.

Results

A total of 198 women with singleton pregnancies aged 15 to 56 years were studied over six months. Their average age was 32.6 years; height range was 146–158 cm; weight range was 45–132 kg; BMI was 17.63–9.08 kg/cm^2, and fetal age was 37–41 weeks with a mean of 38 weeks and four days. The interval between ultrasound scanning and delivery date was 0–3 days. The study found that the mean BW was 3179±387g, ranging from 2500g to 4290g. The mean ultrasound EFW was 3055±378g, ranging from 2500g to 4100g (Table 1). The difference between the mean ultrasound EFW and actual BW (123.81±107.95g) was significant (P=0.0014) in a paired-test, with a significantly positive correlation between BW and EFW (r=0.961, $P=0.000$) (Tables 1 and 2).

The study predicts the BW depending on EFW and found that actual BW=0.9831EFW±175.55g, with strong power for prediction (R^2=0.923) (Table 3, Figure 1).

Table 1.
Mean and standard deviation, range and correlation between maternal factors and EFW, BW

Variables	n	Mean ± SD	Range	*P*-value for ***r***	
				EFW by US	BW
Maternal age, yrs	198	32.63±8.609	15-56	0.013	0.026
Height, cm		159.64±7.092	146-185	0.000	0.001
Weight, kg		73.05±13.469	45-132	0.760	0.904
BMI, kg/cm²		28.77±5.62	17.63-49.08	0.057	0.10
Fetal age, weeks		38.51±1.12	37-41	0.000	0.000
EFW at US, g		3055.99±378.80	2500-4100	--	0.000
BW, g		3179.80±387.67	2500-4290	0.000	--

Table 2.
Pair sample t-test for compare the mean difference between actual BW and US EFW

Variables	Paired Differences					t	df	r	Sig. (2-tailed)
	Mean	SD	Std. Error Mean	95% CI of the Difference					
				Lower	Upper				
BW – EFW	123.81	107.95	7.67225	108.68	138.94	16.138	197	0.961	.000

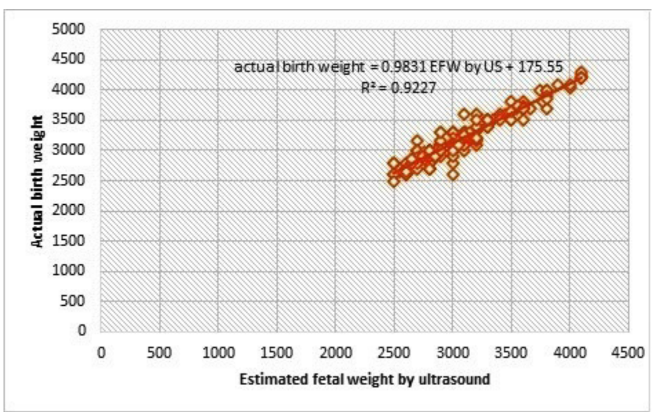

Fig.1

Furthermore, the Wilcoxon signed-ranked test showed that in the 50th percentile, the ultrasound EFW was 3000g, while BW was 3100g, with a z-score of -10.73 based on negative rank (P<0.001) (Table 4).

Table 4.
Wilcoxon Signed-Ranks Test to assess the correlation between BW and EFW by US

Variables	n	Minimum	Maximum	Percentiles			Z score	Sig. (2-tailed)
				25th	50th (Median)	75th		
EFW	198	2500.00	4100.00	2800.00	3000.00	3212.500	-10.730b	0.000
BW	198	2500.00	4290.00	2900.00	3100.00	3425.00		

For the comparison study, three accuracy measures were used to analyze the number of estimates within ±10% of BW, the results showed that the overall mean percentage error was -3.85%, and the overall mean absolute error was 123.81 g (Table 5, Figures 2 and 3).

Table 5.
Mean absolute and percentage errors between ultrasound and birth weight

Birth weight Stratum	Ultrasound EFW
overall	
Mean absolute error	123.81±107.95 (Std. Error 7.76)
Mean percentage error	-3.85±3.45 (Std. Error 0.24)
Error of estimation	26.92 for US EFW, 27.55 for BW
Correlation	0.961*
Fetal weight grouping depending on ultrasound	
2500 ≤ 3000 g (112 fetus)	
Mean absolute error	127.94±114.61(Std. Error 10.83)
Mean percentage error	-4.26±3.85 (Std. Error 0.36)
Error of estimation	13.18 for US EFW, 16.11 for BW
3001≤ 3500 g (57 fetus)	
Mean absolute error	123.33±107.81(Std. Error 14.27)
Mean percentage error	-3.58±3.06 (Std. Error 0.40)
Error of estimation	18.04 for US EFW, 24.67 for BW
3501≥4000 g (24 fetus)	
Mean absolute error	104.79±85.83(Std. Error 17.52)
Mean percentage error	-2.71±2.23 (Std. Error 0.45)
Error of estimation	27.99 for US EFW, 32.40 for BW
More than 4000 g (5 fetus)	
Mean absolute error	128.00±40.86(Std. Error 18.27)
Mean percentage error	-3.02±0.93 (Std. Error 0.41)
Error of estimation	0.00 for US EFW, 18.27 for BW

Table 3.
Prediction of BW depending on ultrasound EFW (regression analysis)

		Unstandardized coefficients		Standardized coefficients	t	Sig.	r	R^2	Std. Error of the Estimate
		B	Std. Error	Beta					
1	(Constant)	175.554	62.573		2.806	.006	0.961	0.923	108.04205
	EFW	.983	.020	.961	48.377	.000			
a. Dependent Variable: BW									

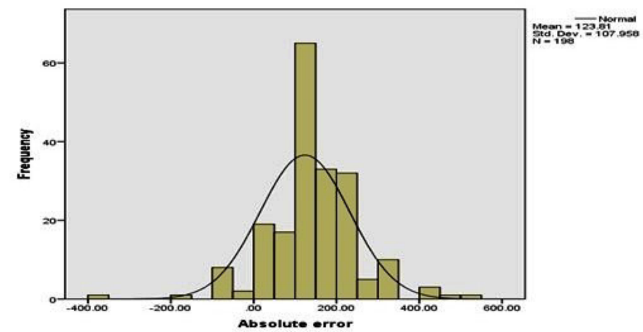

Fig.2.

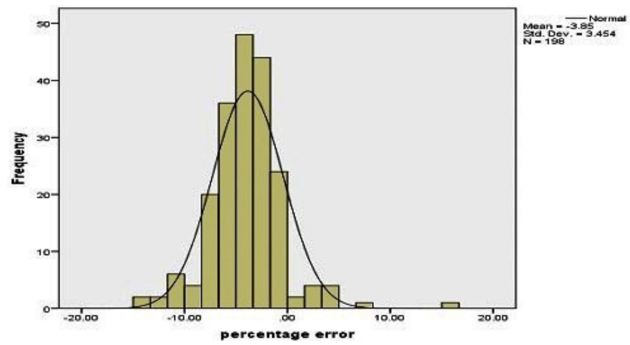

Fig.3.

Table 6.

Bland–Altman plots test to assess the level of agreement between EFW by ultrasound and BW

Bland-Altman			
		95% Confidence Interval	
	Estimate	Lower	Upper
Bias (n = 198)	123.8	109	138.9
Lower limit of agreement	-87.8	-114	-61.9

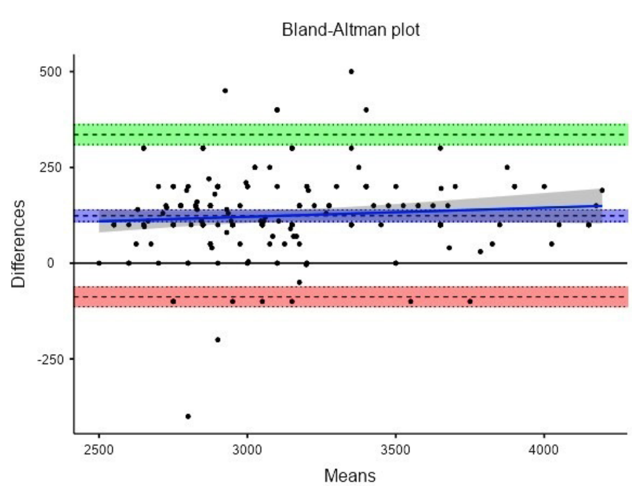

Fig.4.

The Bland-Altman plot showed a strong level of agreement between EFW and BW. The lower limit of the estimate was -87.8, and the upper limit was 335.4. Only a minimal number of estimated cases lie outside the upper and lower agreement limits, showing that ultrasound EFW is a strong predictor of BW (Table 6, Figure 4)

Discussion

Low and excessive FW and intrauterine growth restriction during labor and the puerperium can result in perinatal morbidity, mortality, and long-term neurologic developmental disorders. Therefore, an accurate prediction of antenatal FW is essential to reducing the risk of perinatal morbidity, mortality, and long-term neurologic developmental disorders. In obstetrics, accurate FW prediction is of great concern. Because FW cannot be directly measured, it is calculated based on the fetus and its mother's physical features. Ultrasonographic methods are the most widely used of the various techniques, but only a few studies have examined the accuracy of ultrasonic measures in predicting FW to determine the optimum formula. The accuracy of ultrasound EFW has increased in the past decade, with recent studies consistently producing random errors below 10%. The accuracy of these measurements is attributable to the incorporated parameters. The Hadlock formula 1 is still the most reliable regression method and produces the fewest random errors.(13). We found a significantly positive correlation between ultrasound EFW and BW (r=0 .961, P<0.001). The study also found a significant linear relationship between ultrasound EFW and BW (R^2=0.923). This is consistent with the data of Njoku et al.,(14) who found a positive linear correlation between ultrasound EFW and BW (R^2=0.7646). The results showed that the overall mean percentage error was -3.85%, and the overall mean absolute error was 123.81 g. In Njoku et al.,(14) the mean percentage error was -3.1% and the overall mean absolute error was 123.61 g. Our study results differ slightly from Okafor et al.,(15) who studied 170 Nigerian pregnant women, with 0–2 days' time intervals between ultrasound scan and delivery by using the Hadlock formula 3 to estimate FW. They found that the mean BW was 3.47±0.47 kg, while the mean EFW was 3.43±0.8 kg. A positive correlation was found between the ultrasound EFW and the actual BW (r=0.75, P=0.04), with a mean error of 41.17 g and a mean absolute error of 258.22 g.

Our findings are consistent with those by Basha et al.,(16) who used the Hadlock formula 1 for EFW for pregnant Jordanian women. They yielded acceptable results in terms of actual neonatal weight at birth; additionally, Donma et al.(17) found that Hadlock's ultrasound estimations are superior to Shepard and Nahum's equation.

Furthermore, there is a significant association between the ultrasound EFW and BW with maternal age and height but no significant link between maternal weight and BMI in ultrasound EFW and BW. Many studies have independently confirmed the relationship between an offspring's BW and their adult weight. There is an agreement between this study and a previous one (18) that used the fetal development charts from the World Health Organization for which maternal height and age had a significant effect on fetal growth. In contrast, we found that BMI and maternal weight have no significant effect on EFW and BW.[13,14,19] The Bland-Altman plot showed a strong level of agreement between EFW and BW. The lower limit of the estimate was -87.8, and the upper limit was 335.4 (95% agreement limit). Another study found that the bias was -85.06g. Eze et al.[20] also found strong agreement between EFW by ultrasound and BW. Consistently, our findings agree with a study conducted in Nigeria in which EFW was measured in 282 women with singleton pregnancies by using Hadlock formula 3 in the Bland-Altman plot.[20,21] In that study, a Wilcoxon signed-ranked test showed that in the 50th percentile, the ultrasound EFW was 3000g, while the BW was 3100 g, with a z-score of -10.73 based on a negative rank (P<0.001).

Except for sharing nutrition and access to private health care, there are differences in the habits and lifestyles of different groups in Saudi Arabia. Yet nearly all Saudi Arabian women in the Aseer region do not smoke, drink alcohol, or use hazardous chemicals. Despite multiple studies that have found a correlation between social factors and BW, there are differing perspectives on why this is true. Other factors could include differences in the quality and amount of medical treatment, food, housing conditions, social support and unemployment, and some women may have greater exposure to dangerous chemicals or increased risk of infectious disease. However, more research is needed to improve FW accuracy, ascertain if EFW near delivery improves outcomes, and determine how applicable these methods are to situations that affect BW, such as premature rupture of membranes and obesity, which were not included in the current study.

Conclusion

The significantly positive correlation between EFW by ultrasound and BW indicates that the Hadlock formula 1 for predicting FW is accurate, valid, and effective in the research environment.

Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethical Committee of Scientific Research, King Khalid University Faculty of Medicine with approval number (ECM#89000), (HAPO-06-B-001).

Informed Consent Statement

Written informed consent to publish this paper was obtained from the study participants.

Data Availability Statement

The study protocol can be accessed upon demand by interested researchers if justified. This study is not registered in any repository. The TMMR-RS is registered on ClinicalTrials.gov (NCT01819077).

Competing Interests

The authors declare that they have no competing interests.

Acknowledgments

The authors would like to thank the Deanship of Scientific Research at King Khalid University for their technical support. We also thank the staff of Abha Mahala Hospital for their contributions, cooperation, and support during the survey.

References

1. Bajracharya J, Shrestha NS, Karki C. Accuracy of prediction of birth weight by fetal ultrasound. Kathmandu Univ Med J (KUMJ). 2012 Apr-Jun;10(38):74-6.
2. Ekele B, Otubu JAM. Maternal and perinatal mortality. Textb Obstet Gynecol Med Student Agboola A, Ed 2nd ed Ibadan, Niger Heinemann Educ Books. Published online 2006:526-531.
3. Jahanfar S, Lim K, Ovideo-Joekes E. Birth weight discordance and adverse perinatal outcomes. J Perinat Med. 2017 Jul 26;45(5):603-611. doi: 10.1515/jpm-2016-0089.
4. Kehinde OA, Njokanma OF, Olanrewaju DM. Parental socioeconomic status and birth weight distribution of Nigerian term newborn babies. Niger J Paediatr. 2013 Mar;40(3):299-302. doi: 10.4314/njp.v40i3,20.
5. Westerway SC. Estimating fetal weight for best clinical outcome. Australas J Ultrasound Med. 2012 Feb;15(1):13-17. doi: 10.1002/j.2205-0140.2012.tb00136.x.
6. Ashrafganjooei T, Naderi T, Eshrati B, Babapoor N. Accuracy of ultrasound, clinical and maternal estimates of birth weight in term women. East Mediterr Health J. 2010 Mar;16(3):313-7.
7. Baum JD, Gussman D, Wirth JC 3rd. Clinical and patient estimation of fetal weight vs. ultrasound estimation. J Reprod Med. 2002 Mar;47(3):194-8.
8. Shittu AS, Kuti O, Orji EO, Makinde NO, Ogunniy SO, Ayoola OO, Sule SS. Clinical versus sonographic estimation of foetal weight in southwest Nigeria. J Health Popul Nutr. 2007 Mar;25(1):14-23.
9. Shepard MJ, Richards VA, Berkowitz RL, Warsof SL, Hobbins JC. An evaluation of two equations for predicting fetal weight by ultrasound. Am J Obstet Gynecol. 1982 Jan 1;142(1):47-54. doi: 10.1016/s0002-9378(16)32283-9.
10. Hadlock FP, Harrist RB, Martinez-Poyer J. In utero analysis of fetal growth: a sonographic weight standard. Radiology. 1991 Oct;181(1):129-33. doi: 10.1148/radiology.181.1.1887021.
11. Campbell S, Warsof SL, Little D, Cooper DJ. Routine ultrasound screening for the prediction of gestational age. Obstet Gynecol. 1985 May;65(5):613-20.
12. Nahum GG, Pham KQ, McHugh JP. Ultrasonic prediction of term birth weight in Hispanic women. Accuracy in an outpatient clinic. J Reprod Med. 2003 Jan;48(1):13-22.
13. American Institute of Ultrasound in Medicine. AIUM practice guideline for the performance of obstetric ultrasound examinations. J Ultrasound Med. 2010 Jan;29(1):157-66. doi: 10.7863/jum.2010.29.1.157.
14. Njoku C, Emechebe C, Odusolu P, Abeshi S, Chukwu

C, Ekabua J. Determination of Accuracy of Fetal Weight Using Ultrasound and Clinical Fetal Weight Estimations in Calabar South, South Nigeria. Int Sch Res Notices. 2014 Nov 10;2014:970973. doi: 10.1155/2014/970973.

15. Okafor CO, Okafor CI, Mbachu II, Obionwu IC, Aronu ME. Correlation of Ultrasonographic Estimation of Fetal Weight with Actual Birth Weight as Seen in a Private Specialist Hospital in South East Nigeria. Int J Reprod Med. 2019 Oct 27; 2019:3693797. doi: 10.1155/2019/3693797.

16. Basha AS, Abu-Khader IB, Qutishat RM, Amarin ZO. Accuracy of sonographic fetal weight estimation within 14 days of delivery in a Jordanian population using Hadlock formula 1. Med Princ Pract. 2012;21(4):366-9. doi: 10.1159/000335539.

17. Donma MM, Donma O, Sonmez S. Prediction of birth weight by ultrasound in Turkish population. Which formula should be used in Turkey to estimate fetal weight? Ultrasound Med Biol. 2005 Dec;31(12):1577-81. doi: 10.1016/j.ultrasmedbio.2005.07.017.

18. Stein AD, Lumey LH. The relationship between maternal and offspring birth weights after maternal prenatal famine exposure: the Dutch Famine Birth Cohort Study. Hum Biol. 2000 Aug;72(4):641-54.

19. Kiserud T, Piaggio G, Carroli G, Widmer M, Carvalho J, Neerup Jensen L, Giordano D, Cecatti JG, Abdel Aleem H, Talegawkar SA, Benachi A, Diemert A, Tshefu Kitoto A, Thinkhamrop J, Lumbiganon P, Tabor A, Kriplani A, Gonzalez Perez R, Hecher K, Hanson MA, Gülmezoglu AM, Platt LD. The World Health Organization Fetal Growth Charts: A Multinational Longitudinal Study of Ultrasound Biometric Measurements and Estimated Fetal Weight. PLoS Med. 2017 Jan 24;14(1):e1002220. doi: 10.1371/journal.pmed.1002220. Erratum in: PLoS Med. 2017 Mar 24;14 (3):e1002284. Erratum in: PLoS Med. 2017 Apr 20;14 (4):e1002301. Erratum in: PLoS Med. 2021 Jan 7;18(1):e1003526. PMID: 28118360; PMCID: PMC5261648.

20. Eze CU, Abonyi LC, Njoku J, Okorie U, Owonifari O. Correlation of ultrasonographic estimated fetal weight with actual birth weight in a tertiary hospital in Lagos, Nigeria. Afr Health Sci. 2015 Dec;15(4):1112-22. doi: 10.4314/ahs.v15i4.9.

21. Dimassi K, Douik F, Ajroudi M, Triki A, Gara MF. Ultrasound Fetal Weight Estimation: How Accurate Are We Now Under Emergency Conditions? Ultrasound Med Biol. 2015 Oct;41(10):2562-6. doi: 10.1016/j.ultrasmedbio.2015.05.020.