ORIGINAL ARTICLE

Reliability of Sonographic Estimation of Fetal Weight: A Study of Three Tertiary Hospitals in Nigeria

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ABSTRACT

Context: There is a dearth of sonologists in Nigeria, yet sonographic estimation of actual birth weight (ABW) is important in antenatal care.

Aim: To determine the reliability of estimated fetal weight (EFW) by sonographers and sonologists in Lagos Nigeria.

Settings and Design: In the cross-sectional study, a convenience sample of 663 healthy women with singleton pregnancy at term was selected. Ethical approval for the study design and consent of participants were obtained.

Subjects and Methods: Three sonographers and three sonologists used a single ultrasound scanner with Hadlock-3 algorithm to measure biparietal diameter, abdominal circumference, and femur length in three centers while three midwives used a single neonatal weighing scale to measure ABW.

Statistical Analysis Used: Medical® statistical software version 12.5 was used to analyze data. Descriptive and inferential statistics, as well as Bland/Altman plots were used to determine reliability of EFWs. Results were tested for statistical significance at $P \leq 0.05$.

Results: Majority (76.2%) of babies had normal weight while mean EFW and ABW were 3.50 ± 0.10 kg and 3.45 ± 0.12 kg, respectively and the difference between them is not statistically significant ($P > 0.05$). For sonographers and sonologists in each center, mean error and coefficient of variation were very small while Pearson's correlation coefficient as well as intra- and interclass correlation coefficients was very high.

Conclusion: Independent estimation of ABW by sonographers in Lagos metropolis was very reliable. Sonography was also highly reliable in predicting macrosomia.

Key words: Estimation, fetal weight, reliability, sonography

ملخص البحث:

تهدف هذه الدراسة المستقبلية إلى معرفة دقة تقدير وزن الجنين بواسطة السونار، أجريت هذه الدراسة في ثلاث مستشفيات جامعية، وشملت 663 سيدة حامل بجنين واحد، بينت هذه الدراسة قبل الولادة أن (76.2%) من الأطفال كان وزنهم طبيعيا. لم توجد أي اختلافات ذات دلاله إحصائية تذكر بين الوزن التقديري والوزن الحقيقي ... وتخلص هذه الدراسة إلى أن تقدير الوزن للجنين بواسطة السونار جدير بالثقة.

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INTRODUCTION

Maternal and infant mortality remains a major challenge in Sub-Saharan Africa with an incidence rate of >90%. In 2013, Nigeria had one of the highest maternal and infant mortality rates in the world.[1-3] Obstructed labor (8%) and postpartum hemorrhage (25%) are major causes of maternal mortality.[4] Birth weight is an important parameter that determines the outcome of pregnancy and neonatal survival in the 1st year of life.[5,6] Fetal macrosomia is associated with obstructed labor, shoulder dystocia, birth trauma, and asphyxia.[7] Furthermore, perinatal morbidity and mortality are associated with low birth weight in >16% of live born infants.[7,8]

Optimal antenatal and perinatal care reduces maternal and infant mortality and fetal weight estimation has since been an integral part of routine obstetric care.[5] Estimation of fetal weight, especially in the third trimester of pregnancy, is important to clinicians because that is the period when growth assessment is most likely to influence clinical decisions.[9,10] The clinical method of fetal weight estimation involves measurement of symphysiofundal height and abdominal girth at the level of the umbilicus, whereas the sonographic method involves measurement of multiple fetal biometric parameters, after which fetal weight is computed by the ultrasound scanner using a regression algorithm.[4,10] The ultrasound method is, however believed to be more accurate than the clinical method, hence >20% of all pregnant women now undergo a third-trimester ultrasound examination specifically for the assessment of fetal growth and fetal weight estimation.[6,11,12]

Sonography is, however operator-dependent and errors in estimated fetal weight (EFW) as high as 20% have been reported while adequate training of sonographers, use of well-designed modern equipment and adherence to a standardized scanning protocol reduces observer errors in sonographic EFW.[13] It is standard practice in America for well-trained sonographers to acquire images and sonologists to interpret.[14] However, this is not so in Nigeria because of lack of sonologists.[15] Developing countries with high infant and maternal mortality have therefore, been advised to ensure that there is more emphasis on the training of sonographers.[16]

The majority of sonographers and sonologists in Nigeria are radiographers and physicians respectively. Nigerian sonologists are medically qualified diagnostic radiologists who obtained the West African College of Surgeons Fellowship and or the National Postgraduate Medical College Fellowship in Radiology. Sonographers on the other hand, are radiographers who possess the Bachelor of Science degree in diagnostic radiography before obtaining a Master of Science (M.Sc) degree or a postgraduate diploma (PgD) in ultrasonography. The M.Sc and PgD programs take at least 24 and 12 months respectively to complete. Knowledge acquired during these programs are assessed using formative and summative examinations and candidates are obliged to complete a dissertation and show evidence of successful clinical training by submitting a logbook endorsed by a senior sonographer or sonologist in the hospital where the training was carried out. Such clinical training takes not <6 months and emphasis is always placed on acquiring hands-on experience.

In view of Nigeria's current maternal and infant mortality rate and an acute scarcity of sonologists, encouraging independent sonographic EFW by sonographers has been advocated.[3,15] However, observer error is associated with sonographic EFW, but with adequate training, use of state-of-the-art modern equipment and adherence to standardized scanning protocol errors can be reduced.[17] The reliability of independent EFW by sonographers needs to be assessed to ascertain its usefulness. Unfortunately, formative and summative examinations do not provide adequate long-term feedback or information on the depth of knowledge, competence and skill of sonographers to carry out fetal weight estimation.[18] On the other hand, a reproducibility study to assess agreement within and between replicate EFW by sonographers is a better method of determining the effectiveness of didactic education and training of sonographers.[19,20] Therefore, the aim of this study was to determine the intra- and interobserver reliability of sonographic estimation of actual birth weight (ABW) in three tertiary hospitals in Lagos metropolis, southwest Nigeria, to highlight the usefulness of independent sonographic EFW by sonographers.

SUBJECTS AND METHODS

The prospective cross-sectional study was carried out in three tertiary hospitals (Hospitals A, B, and C) between August 2013 and October 2014. The study design was approved by the Health Research and Ethics committee in each hospital and informed written consent was obtained before participants were recruited.

The study group comprised a convenience sample of 663 women. Only healthy women (absolute body weight >95 kg) with term singleton pregnancy with no sonographically detected fetal anomaly were included because maternal weight, multiple pregnancy and or fetal defects affect the reliability of sonographic EFW.[4,9,21] Pregnancy at term is defined as the period between 37 completed weeks up to and including 41 completed weeks and 6 days of gestation.[22,23] Gestational age (GA), as calculated from each woman's last menstrual period (LMP), was confirmed by standardized sonographic estimation of GA by measuring fetal crown-rump length (CRL) between nine plus zero (9 + 0) and 14 + 0 weeks of gestation. The GA calculated from LMP is deemed accurate if the difference between GA calculated from LMP and CRL is ≤7 days.[22] Furthermore, fetuses with dolichocephaly or those with brachycephaly (normal variants of fetal head shape) were excluded from the study. This is because such fetal head shapes are known to adversely affect the accuracy of biparietal diameter (BPD) measurement.[17]

A single Sichuan-Xukang ultrasound scanner, Model XK/21355 LCD manufactured in 2011 by Sichuan-Xukang Medical Electrical Appliances Co. Ltd., China, with a 3.5MHz convex transducer and Hadlock-3 fetal weight estimation algorithm was used. ABW was measured with a "Crown" neonatal weighing scale manufactured in 2008 by Ramon Surgical Co. Ltd., New Delhi, India. Weekly quality assurance tests were performed on the ultrasound scanner by a medical physicist to ensure optimal performance of all equipment while the weighing scale was standardized for zero error before use.

Three well-trained sonographers each with an M.Sc degree in ultrasonography (designated observer 1 in each center) and three sonologists (designated observer 2 in each center) were recruited to perform sonographic EFW. Each observer had 5 years of experience on obstetric sonography. Biparietal diameter, abdominal circumference (AC), and femur length (FL) were independently measured by each observer who were blinded to each other's measurements to reduce bias following the "ACR–ACOG–AIUM–SRU practice parameter for the performance of obstetrical ultrasound" guidelines.[14]

Biparietal parietal diameter was measured on a transverse image of the fetal skull obtained at the level of the thalami and cavum septi pellucidi but without the cerebellar hemispheres in the plane.[14] The cross-end of the caliper was placed in the outer edge of the parietal bone closer to the probe and then taken to the inner edge of the parietal bone farther from the probe to measure BPD. A true transverse image of the fetal abdomen was obtained at the level of the junction of the fetal umbilical vein, portal sinus with fetal stomach clearly visible.[14] To measure AC, the cursor was placed on the outer border of the fetal abdomen and the ellipse facility used to trace the AC. For FL measurement, an iliac bone was identified and the transducer then maneuvered until the full length of the femur was visible and as horizontal as possible. FL is the distance between outer borders of the diaphysis of the femoral bone.

SONOGRAPHIC ESTIMATION OF FETAL WEIGHT

After BPD, AC, and FL were measured, EFW was automatically computed by the scanner using its regression algorithm. After the first scanning session, participants were randomly called in for subsequent measurements. In all, each subject had two pairs of sonographically EFW. Measurement of ABW: Three experienced midwives (blinded to all EFWs) weighed babies using the same standardized "Crown" weighing scale within 30 min of delivery and before the infant's first feeding.[4] ABW was read to the nearest 0.1 kg only when the baby was most calm and the pointer of the weighing scale at rest.

Data were analyzed using Medical® Statistical Software for biomedical research, version 12.5 (Medical Software, Acacialaan 22, B-8400 Ostend, Belgium). Fetal weight was categorized into normal, microsomia and macrosomia (2.50 kg–4.00 kg, <2.50 kg and >4.00 kg) respectively.[24] Descriptive statistics (mean and standard deviation [SD]) and coefficient of variation (CV) were calculated. Intra- and interobserver agreement between pairs of EFW and ABW was assessed by calculating mean and SD of the difference.[25] Reliability of EFW was determined using Pearson's correlation (r), intra- and interclass correlation coefficients (ICC) with their 95% confidence interval (CI).[19,20] Bland-Altman plot was also used to graphically depict agreement between replicate EFWs and ABWs by observers.[26] Results were tested for statistical significance at $P \leq 0.05$.

RESULTS

The mean age of the population was 30.5 ± 11.3 (range 19–42) years and the majority (245; 36.9%) of the women were in the 31–34 years age range [Table 1]. Table 1 also shows that 76.2% of babies had normal weight at birth while 10.6% and 13.2% were microsomic and macrosomic respectively. The mean EFW in the population was 3.50 ± 0.10 kg while the mean ABW was 3.45 ± 0.12 kg. For the microsomic weight category, the mean EFW was 2.32 ± 0.03 kg while the mean ABW was 2.33 ± 0.10. For normal weight fetuses, the mean EFW was 3.63 ± 0.10 kg, whereas the mean ABW was 3.52 ± 0.10 kg. For the macrosomic weight category, however mean EFW was 4.43 ± 0.17 kg, whereas the mean ABW was 4.50 ± 0.20 kg [Table 2]. Mean intra- and interobserver errors (0.18 kg and 0.17 kg, respectively) between EFW and ABW were not statistically significant ($P > 0.05$) in each center.

Mean EFWs correlated positively with mean ABWs, and Pearson's correlation coefficient (r) was very high and statistically significant ($P = 0.0001$) within and between pairs of EFW and ABW for each weight category in each center [Table 3]. Intra- and interclass correction within and between pairs of EFW and ABW was very high and statistically significant ($P = 0.0001$) [Table 4], whereas CV within and between pairs of EFW and ABW was <5.0% for each observer in each center [Table 5]. Bland-Altman plotting of mean errors between EFW and ABW [Figure 1] clearly showed that only very few measurements fell outside the 95% limit of agreement.

Table 1: Age range of mothers and categories of actual birth weight of babies in each hospital

Maternal age range	
Age range (years)	**Frequency (%)**
19-22	40 (6.0)
23-36	92 (13.8)
27-30	162 (24.4)
31-34	245 (36.9)
35-38	68 (10.3)
39-42	56 (8.5)
Mean±SD=30.5±11.3	663 (100.0)

Categories of actual birth weight				
Hospital	**Microsomia (%)**	**Normal (%)**	**Macrosomia (%)**	**Total (%)**
A	24 (10.8)	170 (76.2)	29 (13.0)	223 (33.6)
B	22 (10.0)	167 (75.9)	31 (14.0)	220 (33.2)
C	24 (10.8)	168 (76.4)	28 (12.6)	220 (33.2)
Total	70 (10.6)	505 (76.2)	88 (13.3)	663 (100.0)

SD – Standard deviation

DISCUSSION

In the study, the number of mothers decreased sharply after the 31–34 years age range. This seems to suggest that most women in the population appear to be less inclined to conceive after reaching 34 years of age. This supports a rather very well-known trend among women and childbirth. Furthermore, a majority of babies who were predicted by sonography to have normal weight actually had normal weight at birth. This is consistent with reported mean ABW of normal full-term babies.[4,9] Furthermore, 10.6% prevalence of microsomia found in the population is significantly lower than 13.0% average for most Asian countries in general and 20.0% in India, in particular. It is also significantly lower than 13.0%

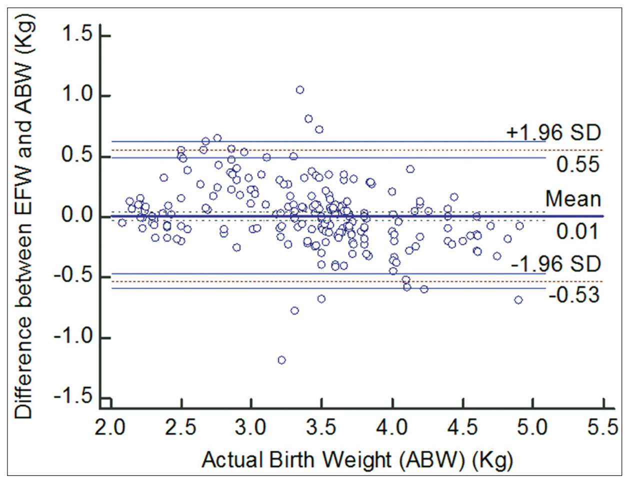

Figure 1: Bland and Altman plots of differences between estimated fetal weight and actual birth weight showing highly significant agreement between estimated fetal weight and actual birth weight.

Table 2: Mean estimated fetal weight and actual birth weight for each weight category in the three centers

Hospital	Mean fetal weight±SD						
		EFW (kg)			ABW (Kg)		
	Observer	Microsomia	Normal weight	Macrosomia	Microsomia	Normal weight	Macrosomia
A	OB 1	2.28±0.04	3.55±0.10	4.35±0.20	2.30±0.05	3.48±0.10	4.48±0.21
	OB 2	2.34±0.06	3.67±0.09	4.43±0.14	2.43±0.06	3.52±0.11	4.45±0.18
B	OB 1	2.33±0.04	3.66±0.11	4.50±0.15	2.33±0.04	3.50±0.10	4.56±0.21
	OB 2	2.38±0.05	3.57±0.09	4.43±0.18	2.35±0.05	3.46±0.08	4.48±0.20
C	OB 1	2.25±0.06	3.61±0.10	4.41±0.20	3.55±0.10	2.25±0.05	4.45±0.19
	OB 2	2.32±0.05	3.69±0.12	4.46±0.16	2.32±0.05	3.58±0.12	4.52±0.20
Mean±SD*		2.32±0.03	3.63±0.10	4.43±0.17	2.33±0.05	3.52±0.10	4.50±0.20
Mean±SD**		3.50±0.10			3.45±0.12		

*Mean±SD – Mean plus standard deviation for each weight category; **Mean±SD – Mean plus standard deviation in the population. OB – Observer; EFW – Estimated fetal weight; ABW – Actual birth weight; SD – Standard deviation; OB – Observer

Table 3: Correlation between estimated fetal weight and actual birth weight

Hospital	Fetal weight category	OB 1			OB 2		
		R	CI	*P*	*R*	CI	*P*
A	Microsomia	0.9928	0.9883-0.9891	0.0001*	0.9925	0.9881-0.9887	0.0001*
	Normal	0.9683	0.9642-0.9685	0.0001	0.9688	0.9647-0.9688	0.0001
	Macrosomia	0.9344	0.9288-0.9351	0.0001	0.9356	0.8793-0.9361	0.0001
B	Microsomia	0.9944	0.9896-0.9936	0.0001	0.9927	0.9886-0.9895	0.0001
	Normal	0.9783	0.9739-0.9783	0.0001	0.9763	0.9668-0.9699	0.0001
	Macrosomia	0.9298	0.9251-0.9324	0.0001	0.9311	0.9275-0.9333	0.0001
C	Microsomia	0.9644	0.9612-0.9640	0.0001	0.9753	0.9730-0.9801	0.0001
	Normal	0.9733	0.9672-0.9757	0.0001	0.9758	0.9716-0.9773	0.0001
	Macrosomia	0.9321	0.9270-0.9554	0.0001	0.9334	0.9316-0.9368	0.0001

*$P<0.05$; *r* – Pearson's correlation coefficient; CI – Confidence interval; OB – Observer

Table 4: Intra- and inter-class correlation between estimated fetal weight and actual birth weight

Hospital	Weight	Intra-class correlation				Inter-class correlation	
		OB 1		OB 2		OB 1 versus OB 2	
		R	95% CI	*R*	95% CI	*R*	95% CI
A	Microsomia	0.9637	0.9363-0.9379	0.9435	0.9358-0.9400	0.9568	0.9256-0.9521
	Normal	0.9483	0.9648-0.9691	0.9688	0.9559-0.9671	0.9392	0.9179-0.9413
	Macrosomia	0.8292	0.8052-0.8253	0.8303	0.8063-0.8295	0.8359	0.8197-0.8535
B	Microsomia	0.9851	0.9842-0.9914	0.9883	0.9832-0.9919	0.9505	0.9359-0.9618
	Normal	0.9586	0.9553-0.9634	0.9672	0.9597-0.9682	0.9026	0.8749-0.9244
	Macrosomia	0.8938	0.8902-0.8975	0.8799	0.8758-0.8860	0.8515	0.8197-0.8535
C	Microsomia	0.9719	0.9689-0.9723	0.9708	0.9694-0.9740	0.9537	0.9308-0.9570
	Normal	0.9535	0.9511-0.9559	0.9481	0.9466-0.9494	0.9209	0.8964-0.9329
	Macrosomia	0.8869	0.8837-8891	0.8930	0.8912-0.8965	0.8407	0.8964-0.9329

CI – Confidence interval; OB – Observer

Table 5: Coefficient of variation within pairs of estimated fetal weight and actual birth weight in each center

Hospital	Fetal weight category	OB	Mean weight±SD (kg)	Coefficient of variation (%)
A	Microsomia	OB 1	2.28±0.04	1.75
		OB 2	2.34±0.06	1.80
	Normal	OB 1	3.55±0.10	2.82
		OB 2	3.67±0.09	2.45
	Macrosomia	OB 1	4.35±0.20	4.60
		OB 2	4.43±0.14	3.20
B	Microsomia	OB 1	2.33±0.04	1.72
		OB 2	2.38±0.05	2.10
	Normal	OB 1	3.66±0.11	3.00
		OB 2	3.57±0.09	2.5
	Macrosomia	OB 1	4.50±0.15	3.30
		OB 2	4.43±0.18	4.06
C	Microsomia	OB 1	2.25±0.05	2.20
		OB 2	3.69±0.12	2.10
	Normal	OB 1	2.32±0.05	2.80
		OB 2	3.61±0.10	3.00
	Macrosomia	OB 1	4.46±0.16	3.58
		OB 2	4.43±0.17	3.84

OB – Observer; SD – Standard deviation

reported for most countries in Sub-Saharan Africa by UNICEF.[27,28] The 13.2% prevalence of macrosomia found in our study is however, higher than 11.8% prevalence reported among Iranians.[29] Reasons for the disparity in fetal weight may include racial factors, maternal age, nutrition and social habits.

Standard deviation of the mean was very small for EFW and ABW in each weight category in the study. SD is an index of variability which determines the level of agreement between replicate measurements. When SD is very small, agreement between replicate estimations performed under the same condition is very high and shows that a given measurement can easily be reproduced.[19] This implies that the EFW performed by sonographers and sonologists included in the study was very reliable. Moreover, calculated mean intra- and interobserver errors are also inferential statistics used to estimate variability. Since both were very small and not statistically significant ($P > 0.05$) within and between pairs of EFW and ABW for each observer in each center, they also support the fact that agreement between replicate EFW and ABW performed by the two observer groups was very high and, therefore, reliable. These results suggest that the sonographers studied appear to have acquired the adequate skills needed to independently perform useful EFW.

In the study, we found that Pearson's correlation coefficient (r with its 95% CI) and intraclass correlation (ICC) were quite high and statistically significant ($P < 0.0001$). When Pearson's correlation coefficient (r) with its 95% CI and intra- and interclass correlation coefficient (ICC) are high and statistically significant, they indicate easy reproducibility, a high level of agreement and reliability of replicate measurements (EFW and ABW in this case) performed under the same conditions.[19,20] This implies that EFW in the study was easily reproducible and therefore, reliable predictors of ABW. Similar results have been reported with sonography said to be "highly accurate" in the estimation of ABW.[8] Quite remarkably, however both coefficients were highest in the estimation of microsomia but least in the estimation of macrosomia, either by sonographers or sonologists in each center, thus suggesting that sonography appears to be slightly more reliable in the prediction of microsomia than macrosomia. This agrees with some researchers who had earlier reported that sonography tends to show the least absolute percentage error in the prediction of microsomia.[4,8,9,17] Since differences between mean errors in EFW and ABW were not statistically significant ($P > 0.05$) within and between pairs of measurements in each center, the clinical significance of this result is not clear.

In this study, CV was <5% in each weight category for each observer in the three centers but was least in the estimation of microsomia and highest in the estimation of macrosomia. CV (range = 1–100%) is the ratio of the SD to the mean and refers to the level of disparity between replicate measurements performed under the same condition.[30,31] Very low CV between replicate measurements in this study indicates very good agreement between replicate measurements as well as easy reproducibility of such measurements. We can, therefore, conclude that EFW by the two observer groups in the study were quite easily reproducible and therefore, reliable since CV was very small for each observer in each weight category. These results support opinions earlier expressed by some researchers who carried out similar studies.[4,9] Furthermore, these small CVs seem to suggest that sonography appears marginally more accurate in predicting microsomia than macrosomia.

The trend followed by Bland and Altman plot of mean errors between EFW and ABW in our study depict highly significant agreements within and between pairs of EFW and ABW [Figure 1] as only very few measurement errors fell outside the 95% limit of agreement. These plots appear to support Pearson's correlation coefficient, ICC, and CV, in suggesting that EFW by sonographers and sonologists was very reliable in the population studied. There was however, a similar pattern of clustering of errors around microsomic and macrosomic weight categories suggesting that sonography may actually be very highly reliable in detecting both microsomia and macrosomia. Some researchers, however had earlier reported that sonography appears to be poor in the assessment of macrosomia.[4,9,17] In spite of this, we are convinced that errors associated with sonographic prediction of macrosomia might be of limited clinical significance.

The localized nature of this study appears to be a major limitation in that only Lagos metropolis was studied in A large country such as Nigeria. The sample studied may, however be considered suitable because studies on the reliability of sonographic measurements involve multiple measurements and most investigators tend to prefer a moderate sample. Moreover, BPD is no longer used in fetal weight estimation in some countries such as the United Kingdom because head shapes adversely affect the accuracy of BPD measurement.[17] In Nigeria, BPD is still widely used, but we ensured that all fetuses with dolichocephaly or brachycephaly were excluded from the study.

CONCLUSION

Fetal weight independently estimated by sonographers and sonologists in Lagos metropolis was very reliable; therefore, well-trained and experienced sonographers who follow a standardized scanning protocol and use a state-of-the-art modern ultrasound machine can independently perform useful fetal weight estimation. Moreover, sonography appears to be highly reliable in detecting macrosomia.

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Conflicts of interest

There are no conflicts of interest.

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