

New Sudanese Reference Chart of Fetal Biometry and Weight Using Ultrasonography

Caroline Edward Ayad¹, Ahmed Abdelrahim Mohammed Ibrahim²,
Mohammed Elfadil Mohammed GarElnabi¹, Bushra Hussein Ahmed³,
Elsafi Ahmed Abdalla¹, Mohammed Ahmed Elshiekh Saleem¹

¹College of Medical Radiological Science, Sudan University of Science and Technology, Khartoum, Sudan

²Faculty of Radiology Science and Medical Imaging, Alzaiem Alazhari University, Khartoum, Sudan

³College of Medical Radiological Science and Nuclear Medicine, The National Rabat University, Khartoum, Sudan

Email: carolineayad@yahoo.com

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Abstract

Background: Many centers in Sudan use the reference data for fetal biometry. The recently published population-based reference either overestimated or underestimated the weight of the fetuses. **Objective:** To establish a national reference for fetal biometry, and weight by gestational age for singleton fetuses in Sudan. **Methods:** Data were collected on all singleton live births documented in the data collection sheet done at Saudi Hospital from 2015 to 2016 (n = 225). Gestational age estimation was based on the last menstrual period and fetal ultrasound thereafter. Fetal biometry and weight and other 6 fetal weight formulae were assessed. Reference data for fetal growth by gestational age were created. **Results:** New charts and reference equations are reported in Sudanese population for fetal biparietal diameter, head circumference, abdominal circumference and femur length and fetal weight. **Conclusion:** We advocate that these reference charts and equations for fetal biometry and weight might be valuable in the clinical use for appropriate ethnic Sudanese.

Keywords

Fetal Biometry, Fetal Weight, Gestational Age, Ultrasonography

1. Introduction

Reference data for birth weight, fetal biometry were first published in the 1970 [1] [2] and revised on a regular

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basis subsequently [3]-[9]. The anthropometric reference curves formulated by Usher and McLean [2] are still in use in some departments [10].

Ultrasound examination and measurement of fetal biometry have become an integral part of recent obstetric care. These measurements can serve for measuring the gestational age (GA) or assessment of fetal development. Selection of the appropriate reference charts is of great importance to ensure accurate diagnosis. Some published reference charts are blemished [11]. Appropriate methods have been published [11] [12] and fetal biometry charts and equations for various populations are now available in the open literature [13]-[18]. It is well known that ethnicity has a significant influence on fetal biometry [19] [20].

There are main difficulties in establishing reference growth curves for newborns: firstly, the calculation of gestational age, which together with intrauterine growth determines the birth weight. Anthropometric studies that calculate gestational age by the last menstrual period may yield systematic differences from those that use obstetric methods, such as early fetal ultrasound or neonatal examination [13]-[16] [20]. Secondly, LMP-based gestational age determinations are limited by many causes [13]. This phenomenon was very apparent on comparison of the population-based Canadian growth reference [7] with data published by Alexander and collaborators [5] in the United States and by Dolberg *et al.* [8] in Israel. The second challenge in establishing a reference chart is the identification and exclusion of live births with improbable values of birth weight for gestational age [18] [19].

Cross-sectional reference charts and equations from the ethnic Sudanese population using appropriate methodology have not previously been published in the open literature. The aim of this study, therefore, was to construct reference charts and equations for fetal biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL) and fetal weight in the ethnic Sudanese.

2. Materials and Methods

2.1. Study Population

The data of this prospective study were obtained from 225 Sudanese pregnant ladies with uneventful pregnancies (Normal); attending the designated study area during the study period (December 2015-March 2016), with singleton pregnancies at second and third trimester with viable fetus. Pregnancies with established diagnosis of hypertension, diabetes were excluded. Mean maternal age/years (27.15 ± 5.86), weight/Kg (79.32 ± 10.39), height/cm (164.67 ± 5.65), BMI (2.93 ± 0.37), parity (2.66 ± 1.69). Verbal consent was firstly obtained from all potential participants. The aims, benefits of the present study were explained to all participants in details. Medical, obstetric and gynecological history of all study subjects posing as (sample) were thoroughly reviewed directly from participants themselves and those with conditions that may in any way, alter the findings of the current study were excluded.

2.2. Measuring of Fetal Weight

Sonographic examination was obtained for all participants (225 pregnant ladies) in supine position using Ultrasound machine with curvilinear probe and transducer frequency of 3.5 MHz. The procedures were explained for participants before the scanning. Singleton pregnancy of (60 fetuses out of 225), were included on the study to measure their fetal weights after delivery using weight caliber. Fetuses with congenital anomalies, the biometric measurements of those, which were unable to ascertain due to reasons like deeply engaged head, were excluded from the study. Biparietal diameter (BPD) measurement was taken from the outer edge of the fetal proximal skull bone to the inner edge of the distal bone. The head circumference (HC) was calculated using electronic ellipse available on the ultrasound scanner. The fetal abdominal circumference (AC) was measured in standard transverse planes at the levels of the stomach and umbilical vein-ductus venous complex. The femur length (FL) was measured from the proximal end of the greater trochanter to the distal metaphysis. Gestational age and fetal weight were calculated. Estimated fetal weight from each equation was calculated separately using basic biometric values for estimation of fetal weight measured automatically by the ultrasound machine. The fetal biometric measurements which were taken previously for the planned delivery were collected in a data sheet. The actual birth weights for 60 babies out of 225 fetuses were also entered into the data sheet after the delivery of the fetuses. With the collected measurements done by ultrasound machine and the estimated measurement done for every fetus, 6 different EFWs formulae (Hadlock *et al.*, I, II, III, 1V, Campbell and Sheppard) [21] were tested.

The validity of these 6 formulas in predicting the actual FW in the study population was tested after comparison with the actual fetal weights. The fetal biometry necessary for measuring the fetal weight was as follows {Sheppard (BPD, AC), Campbell (AC), Hadlock I (AC, FL), Hadlock II (BPD, AC, FL), Hadlock III (HC, AC, FLx HC), Hadlock IV (BPD, HC, AC, FL)} [22]. Actual birth weights of all the fetuses were taken separately. The birth weights were measured by trained nurse.

2.3. Data Analyses

Data were analyzed using Statistical Package of Social Sciences (SPSS) (Inc., Chicago, Illinois version 16). The data obtained were analyzed statistically by computing descriptive statistics: Mean, \pm SD values and percentages. Paired t-test was used for testing the differences between the formulae results. The difference at value of $p < 0.05$ will be considered significant.

3. Discussion

Ultrasonography is routinely used to estimate the fetal weight and is often used as a proxy to actual birth weight. Many ultrasound estimated fetal weight (EFW) formulae have been designed and these are based on different fetal biometric parameters [23] [24]. Use of ultrasound in predicting birth weight is more precise in early gestations, however at term there is significant worsening due to fluid to fetus ratio reduction, bony structures become increasingly calcified, and the vertex descends in the pelvis, making measurements of head circumference and biparietal diameter more difficult [25]. There is no systematic evaluation of the established ultrasound EFW in predicting actual birth weights in the Sudanese population.

Therefore the aim of this study was to test 6 common applied fetal weight formulae and validate the established EFW formulae depending on the dating of gestational age to predict actual birth weight in Sudanese pregnant ladies as well as to provide reference equations for biometric measurements. The data were collected for the purposes of this study rather than being obtained from an available clinical dataset. Data for the study were obtained from only one designated ultrasound examination from each lady. Pregnancies complicated with congenital abnormalities were excluded. Mean and standard deviation of the fetal biometric measurements taken from 225 fetuses were presented in (Table 1).

Numerous formulae have been published for the purpose of estimating fetal weight from a variety of sonographically obtained biometric measurements. Biparietal diameter (BPD), head circumference (HC), Abdomen circumference (AC) and femur length (FL), most commonly, a combination is used [26] [27]. An accurate means of estimating fetal weight using ultrasonography was first described by Campbell 1975 [26]. The most popular formulae are Sheppard, Warsof's [28] with Sheppard's modification [29] and Hadlock [27] [30]. These formulae are included in most ultrasound equipment packages, even though Sonographic machines offer various different formulae for estimation of fetal weight. Table 2 presented the new established equation that was applied to estimate the Sudanese fetuses' weights. Table 3 presented the estimated fetal weight which was evaluated using six formulae as well as the measured weight for Sudanese and was classified according to GA. Figures 1-4 show the positive linear relationship between the gestational age/weeks and BPD/cm, FL/cm, HC/cm and AC/cm. The biometric measurements increased significantly/week for Sudanese fetuses at $p = 0.000$. The contribution of the FL scores the highest values on predicting the GA constituting 99% in both the second and third trimesters.

Table 1. Mean and standard deviation of the fetal Biometric measurements {biparietal diameter (BPD), the head circumference (HC), abdominal circumference (AC), femur length (FL)}, Gestational age and Estimated Fetal Weight/Kg measured by Ultrasound Machine.

Fetal Biometric Measurements						
	BPD (cm)	FL (cm)	HC (cm)	AC (cm)	Gestational Age/Weeks	Estimated Fetal Weight/Kg measured by Ultrasound Machine
Mean	8.16	6.25	3.01	2.71	32.51	2.09
Standard deviation	± 1.60	± 1.39	± 0.53	± 0.59	± 6.17	± 1.04

Table 2. Shows the Correlations Coefficients between the New estimation method for fetal weight/Kg measurement (Dependent variable) and the measured GA and HC for Sudanese.

Model	Unstandardized Coefficients		t	Sig.
	B			
(Constant)	-2.848		-29.269	0.000
GA	0.211		17.139	0.000
HC	-0.634		-4.528	0.000

Dependent Variable: EFW/Kg

The New established equations For Sudanese are as follows: $EFW_{GAHC} = \{(-2.848) + (0.211 \times GA) + (-0.634 \times HC)\}$.

Table 3. Mean and standard deviation of the estimated fetal weight measured for 225 singleton pregnant ladies and evaluated by the (FW formulae) and the New Method For Fetal weight estimation (EFW_{GAHC}).

	The Six Tested Formulae For Fetal weight estimation						New Method For Fetal weight estimation
	Campbell	Sheppard	Hadlock I	Hadlock II	Hadlock III	Hadlock IV	* EFW_{GAHC}
Mean	3.69	3.17	2.59	2.67	2.41	1.53	2.11
Std. Deviation	0.16	0.27	0.27	0.28	0.23	0.25	0.98

*A positive correlation was found between EFW_{GAHC} using our new formula and the actual BWs of 60 newborn babies. The correlation is significant at $p \leq 0.005$.

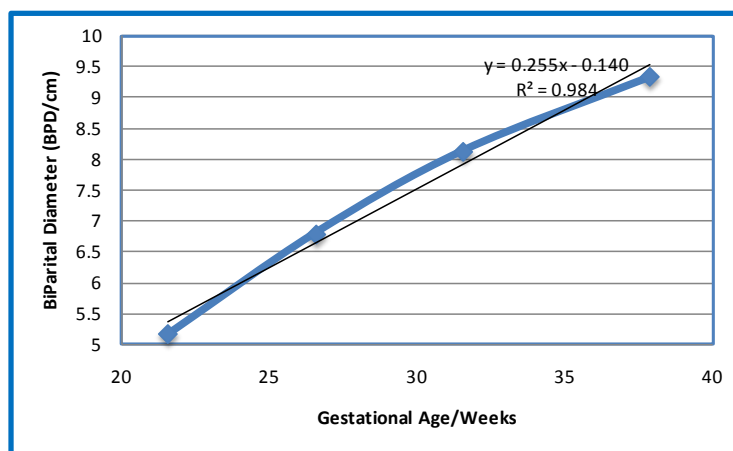


Figure 1. Scatter plot diagram that shows the positive linear relationship between the gestational age/weeks and BPD/cm the BPD increased by 0.26 cm/week for Sudanese fetuses. The contribution of the BPD on predicting of the GA is 98%. $R^2 = 0.984$, $p = 0.000$.

Our sample including a gestational age between 21.55 and 37.85 weeks of gestation and fetal reference charts for usage among the Sudanese population was established (Figures 1-4). Our study has established new equation and chart for sonographic evaluation of the sudanese fetal weight as presented in Table 2 and Table 4. Other studies previously indicated that size charts should not be used for dating pregnancies, and accurate dating requires consideration of gestational age as a function of fetal size [31].

It is well known that ethnicity has a significant influence on fetal biometry [19] [20] as well as small for gestational age carries a higher risk of various adverse outcomes in the perinatal period [32]-[37]. This is why it is important to establish a reference chart for measuring the GA and fetal weight for Sudanese. Precise estimation of fetal weight is the goal in the clinical practice. In the current study, fetal weight estimation using 6 formulae

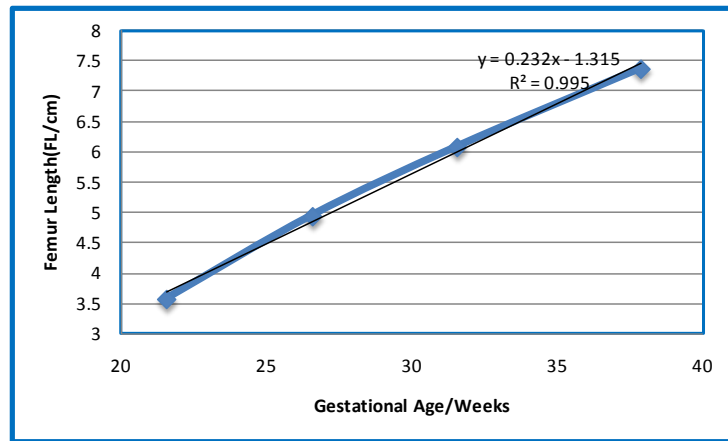


Figure 2. Scatter plot diagram that shows the positive linear relationship between the gestational age/weeks and FL/cm. The FL increased by 0.23 cm/week for Sudanese fetuses. The contribution of the FL on predicting of the GA is 99% $R^2 = 0.995$, $p = 0.000$.

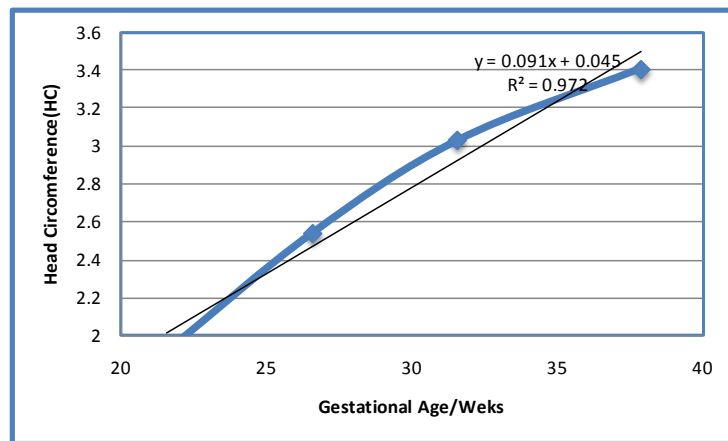


Figure 3. Scatter plot diagram that shows the positive linear relationship between the gestational age/weeks and HC/cm. The HC increased by 0.09 cm/week for Sudanese fetuses. The contribution of the HC on predicting of the GA is 97% $R^2 = 0.972$, $p = 0.000$.

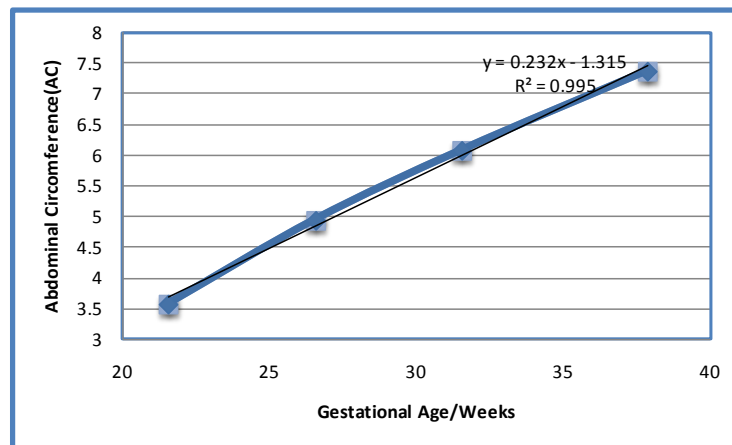


Figure 4. Scatter plot diagram that shows the positive linear relationship between the gestational age/weeks and AC/cm. The AC increased by 0.23 cm/week for Sudanese fetuses. The contribution of the AC on predicting of the GA is 99% $R^2 = 0.995$, $p = 0.000$.

Table 4. New Chart for the Sudanese fetal weight measured by (Fetal birth weight estimation Formulae: Campbell, Sheppard, Hadlock I, Hadlock II, Hadlock III, Hadlock IV) and EFW/Kg measured by ultrasound machine and the new established equation (EFW_{GAHC}) for Sudanese weight measurements classified into classes according to gestational age (GA), R² and p value.

New Chart for the Sudanese fetal weight*								
GA/weeks	Campbell	Sheppard	Hadlock I	Hadlock II	Hadlock III	Hadlock IV	EFW	EFW _{GAHC}
21.5	4.0148	2.6592	2.06	2.1328	1.964	1.0452	0.4442	0.408201
26.55	3.8315	2.9387	2.3356	2.4151	2.1946	1.2967	0.9839	1.097717
31.55	3.6849	3.1653	2.5612	2.6474	2.3842	1.5021	1.8455	1.897938
37.85	3.5692	3.3676	2.8094	2.8943	2.5919	1.7288	2.9615	2.938063
R²	0.976	0.984	0.993	0.993	0.994	0.994	0.998	0.998
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*Fetuses weight ranged between 1.86 to 3.987 Kg.

based on the fetal biometric measurements (BPD or HC, FL, and AC) that was used on most of the biometry were tested. Birth weight is influenced by maternal ethnicity [20] but to the best of our knowledge no data are available for Sudanese fetal weight measured by pregnancy dating for determination of fetal/birth weight according to GA. **Table 2** presented the new method for fetal weight estimation for Sudanese: The New established equation is as pursues:

$$EFW_{GAHC} = \{(-2.848) + (0.211 \times GA) + (-0.634 \times HC)\}$$

The tested formulae with EFW/Kg measured for 225 fetuses by ultrasound machine, showed significant relations at $p \leq 0.005$ as seen in **Table 4**.

Results of assessment of the fetal weight formulae showed that the significant highest positive significant correlation between the fetal weight and GA was seen in the weight estimated by ultrasound machine and our new established equation EFW_{GAHC}. ($R^2 = 0.998$ at $p \leq 0.000$) followed by Hadlock III and IV equations having an equal values ($R^2 = 0.994$ at $p \leq 0.000$) then Hadlock II ($R^2 = 0.993$, $p \leq 0.000$), Sheppard ($R^2 = 0.984$, $p \leq 0.000$) and lastly Campbell ($R^2 = 0.976$, $p \leq 0.000$) with significant high degree of negative correlation. The New established equation EFW_{GAHC} is the best formula identified in our study to predict Sudanese babies weight ranged between 1.86 Kg to 3.987 Kg (**Table 4** and **Figure 5**).

This equation is valuable in the Sudanese babies' weight ranged between 1.86 Kg to 3.987 Kg and the gestational age between 21.55 and 37.85 of gestational. A positive correlation was found between EFW_{GAHC} using our new formula and the actual BWs of 60 newborn babies. The correlation is significant at $p \leq 0.005$.

In this study, the mean Estimated Fetal Weight/Kg EFW was 2.09 Kg \pm 1.04 SD and the mean Gestational Age/Weeks was 32.51weeks \pm 6.17 (**Table 1**). We formulate a growth formula based on ultrasound measurements for fetuses between 21.55 and 37.85 of gestational. Hadlock and colleagues also formulated an optimum growth equation based on ultrasound measurements between 10 and 41 weeks of gestation of Caucasian pregnant ladies [2] [38] but their formula was not popular as it often either under or over estimated the fetal/birth weight in other populations. In order to overcome the limitation of their study an individualized reference charts using Sudanese formula were established (**Table 2** and **Table 3**) and the weight reference and biometry can be applicable according to the mean birth weight at 41.6 weeks of gestation for the local population using above equation. This study validates the fetal/birth weight reference derived from WHO data [39] for birth weights adapted to Sudanese. Comparing the Sudanese fetal biometry with the other populations, it showed difference with the Caucasian, French, UK, Singaporean and Chinese populations [40].

The difference in these measurements among the different populations illustrates the importance of selecting charts appropriate for one's own population.

4. Conclusion

In conclusion, we have constructed a new set of reference data for fetal biometric measurements and equation

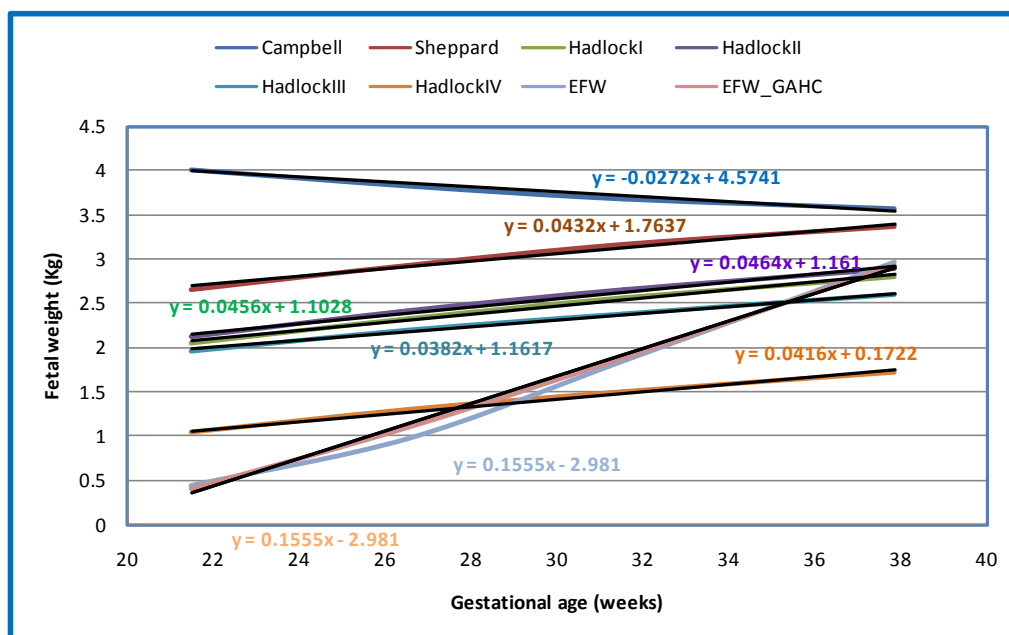


Figure 5. The linear relationship between the gestational age/weeks and fetal weight/kg estimated by 6 ultrasound formulae, ultrasound machine and the new established equation for Sudanese fetuses. (R^2 {Campbell = 0.976, Sheppard = 0.984, Hadlock1 = 0.993, HadlockII = 0.993, HadlockIII = 0.994, HadlockIV = 0.994, EFW = 0.998, EFW_GAHC = 0.998}) significant at $p \leq 0.000$.

for dating (GA) of pregnancy for Sudanese singleton pregnancies. We believe that our charts are ready for clinical use among appropriate ethnic Sudanese groups. We believe our newly growth references for HC might urge Sonologists to include HC measurement as a mandatory part of the routine ultrasound examination.

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