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Research Article

Johnson's Formula for Predicting Birth Weight in Pregnant Mothers at Jimma University Teaching Hospital, South West Ethiopia

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Keywords

- Johnson's formula
- Fetal weight estimation
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- Jimma

Abstract

Background: Accurate assessment of fetal weight is important for optimal obstetric management of labouring mothers. Among the methods of fetal weight estimation, symphysis fundal height measurement is an easier method of fetal weight estimation and has been shown to be as good as ultrasound estimation at term, giving estimates that are correct to within 10% of the birth weight in 60% to 70% of cases.

Objective: The objective of this study is to evaluate Johnson's formula for predicting birth weight in pregnant mothers at JUTH, south western Ethiopia, 2014.

Methods: A cross sectional study was conducted in Jimma University teaching Hospital and 334 mothers were included just before delivery. Symphysis fundal height measurement was performed and the EFW resulting from Johnson's formula was compared with the actual birth weight. The difference between the EFW and the birth weight in each case was calculated and expressed as absolute percentage error, given as the absolute value of the difference divided by the birth weight, multiplied by 100. If the EFW using Johnson's formula is within 10% of the actual birth weight it is considered accurate. And if at least 60% of the EFW by Johnson's formula are accurate it will be used by our community. But if it is accurate in less than 60% of the sample size we will build a regression model for all maternal sociodemographic and obstetric factors as independent variables and birth weight as dependent variable after preparing dummy tables for categorical variables.

Results: The accuracy of Johnson's formula was 38%. The minimum weight difference of the entire sample was 0 and the maximum was 1540 gm with the mean absolute weight difference of 512 gm. The newly derived formula considering predicting variables is: EFW (gm) = -3124.333+103 (Gestational Age in week) + 58(SFH in cm) + -155(membrane status) (1=intact, 0=ruptured membrane): (R2 = 0.62, p-value = 0.00). By looking at the scatter plot of the regression model we have derived a simple clinical formula which is easily remembered as: Estimated fetal weight (gm) = 2600 + 115(symphysis fundal height (cm) - 30).

Conclusion: Johnson's formula was found to be inaccurate in this study among the studied population.

Recommendation: Johnson's formula should not be used for our community. We recommend using the formula: Estimated fetal weight (gm) = 2600 + 115(symphysis fundal height (cm) - 30).

INTRODUCTION

Fetal weight is a very important factor based on which decision must be made concerning labor and delivery. The prevalence of obstructed labour at JUSH, our study area, is 12.2 % [1-5]. Neonatal morbidities associated with obstructed labour are cerebral edema, neurological damage, hypoxia and asphyxia during or after the delivery. LBW or VLBW foetuses, fetal death, birth asphyxia, meconium aspiration, neonatal hypoglycaemia.

To prevent or treat the fetal, neonatal and maternal morbidities and mortalities associated with LBW and macrosomic neonates, accurate estimation of fetal weight is very important.

There are 2 common methods to estimate fetal weight; clinical methods (includes palpation method, SFH measurement) and sono graphic evaluation .Ultrasound study forms a very important tool in modern obstetrics.

The accuracy of clinical methods of fetal weight estimation

was similar to sonographic estimation at term [6-8]. Clinical methods of estimation of fetal weight has been shown to be as good as ultrasound at term, giving estimates that are correct to within 10% of the birth weight in 60% to 70% of cases. In developing countries, ultrasonography may be unavailable or may not be affordable by patients. Even if available, such measurements may be inaccurate during labour and at term [9]. Clinical palpation of the abdomen in estimating fetal weight requires considerable experience and training. SFH measurement with a tape - measure seems a simple clinical method because it is cheap, readily available, non-invasive and acceptable to patients [10]. Furthermore it is a reproducible technique that is easily learned.

After taking the SFH yet it still presents problems with conversion of a measurement to fetal weight estimate. A prediction formula for birth weight has been first deduced from SFH by Johnson. Johnson's and Toshach (1954), determined that a fetal birth weight of 3300 corresponded more closely with a fundal height of 34 cm and a centimeter change in fundal height corresponded more closely with a 150 g change in fetal birth weight [11,12]. They introduced a refinement to this method by correcting for descent of the present part into the pelvis and maternal obesity to the following equation: EFW= 3300 + (SFH + S+O- 34) (150) where S is the correction term for station and 0 is the correction term for obesity. In1957, Johnson's simplified the equation to, EFW= 155(SFH+ S+O- 12) for the same variables. The standard deviation for both equations is 353 g.

Johnson's and Toshach, who claimed an accuracy within 240 g in 68 % and 375gm in 75% of 200 women examined [13,14] was validated in different countries and most studies done have confirmed that Johnson's formula correctly predicts actual birth weight from 61 to 72 % [15-17].

According to a study done in Thailand, the overall accuracy of Johnson's formula within 10% of the actual baby weight was 71.5% [15]. The difference between the estimated weights using Johnson's formula was an average of 227 g higher than the actual baby weight.

8 years later a similar study done in Thailand reveals that the rates of estimates within 10% of actual birth weight was only 35.71% overall: and the rates of estimates by baby weight category of high birth weight, appropriate birth weight, and LBW were 66.67 %,35.90%, and 16.67% respectively [16]. While a study done in Brazil shows that Johnson's formula accurately predicts birth weight in 61% over all. The researcher explained this due to shape difference between Thailand pregnant women and other similar studies with different populations [17].

A comparative study done in India in 2010 showed that Johnson's formula correctly predicts birth weight in 71% overall [18]. While according to a similar study done 6 years before in India shows that Johnson's formula correctly predicts birth weight in 63.5% overall [19]. A regression analysis of a Bangladesh study done 2 years back showed that SFH, maternal height and maternal weight explained respectively 59%, .011% and .009% of observed variation of birth weight. And concluded that SFH-derived birth weight centiles are useful alternatives to ultrasonography especially in the birth weight range 2500-3999g [20].

In Ethiopia most of our population are rural based who have no access to ultrasonography we assess the birth weight by measuring symphysis fundal height by using Johnson's formula. To the best of the authors knowledge there is no a simple and easy formula that transforms a symphysis fundal height values accurately to estimated fetal weight that is validated and found to be clinically useful in a specific population. The only research done in Ethiopia is a comparative study between Johnson's formula and the palpation method [21]. According to this study rate of estimates within 10% of actual birth weight was significantly higher for the palpation method (65%, versus 38%). For birth weights less than 2500 grams both methods overestimated the birth weight; the mean error of the palpation method was significantly smaller than those of the Johnson's method. In the 2500-3999 birth weight range, only the palpation method had no systematic error, whereas the Johnson's method systematically overestimated the birth weight. The mean errors of the palpation method were significantly smaller and a rate of birth weight +/- 10% significantly higher than those of the Johnson's method (68% versus 40%). In the larger weight (>4000 gms), the Johnson's method had less systematic error compared to the palpation method (mean percent error = -0.9 + 11.3. p =0.42), although the small sample size in this group precludes a firm conclusion of the issue in this category. And finally concluded that estimation of fetal weight by the palpation method appears to be more accurate than the Johnson's method. In the lower and average birth weight range the palpation method is the more accurate of the two, while in the higher weight category the Johnson's method appears to be more accurate.

Other variables which will affect the SFH measurement not considered in the above studies, are the inter and intra observer variability: previous papers have indicated that the inter and intra observer variability of SFH measurements is small, ranging from 0.52 cm to 1.72 cm [22-24].

The present study aims in finding out whether Johnson formula is suitable for our regional specific population and in case the accuracy of Johnson's fomula is less than a 60 to 70%, the author will attempt to derive a new formula that is better suitable for this population. The development and validation of simple, effective and inexpensive tools for reproductive health are important worldwide and especially relevant in developing countries, where high-cost equipment like ultrasound and trained technicians are scarce.

METHODS AND MATERIALS

Background information of the study Area and period

Jimma is located 357 Kms South West of Addis Ababa and has total area of 4,623 hectares. The town is divided in to 3 Woreda or Higher and 13 Kebeles .The total projected population of the town is 207,573 according to 2011 central statistical agency of Ethiopia. It has 2 governmental hospitals (JUTH and Shenen gibe hospital), 4 health centers and one military hospital. The study was conducted in JUTH from May 1st to August 30, 2014. JUTH is a tertiary hospital receiving referrals from the surrounding health

centers and hospitals around Jimma town. The maternity building wards consists 40 beds serving for postnatal, post caesarean section, high risk women admitted for elective termination. The labor ward has 8 beds for following women in active first stage of labour and 4 beds to attend second stage. There is also a private room for patients opting for private care.

Study design: A cross-sectional study design was employed.

Source population: All mothers admitted to the labour and maternity ward were considered as source population for the study.

Study population: The study population was all selected women admitted to the labour and maternity ward during the study period who fulfil the inclusion criteria and are not in the exclusion criteria.

Inclusion criteria: Labouring mothers admitted to the labour ward for delivery who were either in true labour or delivery is decided and mothers admitted to the maternity ward when they are transferred to the labour ward for delivery due to onset of spontaneous labour, for elective induction and when they are prepared for elective or emergency cesarean section: singleton pregnancy, live fetus, with a longitudinal lie and cephalic presentation.

Exclusion criteria: Abortus, known severe fetal congenital anomalies, polyhydramnios (amniotic fluid index greater than 24 cm or clinically assessed), known fibroid or congenitally abnormal uterus.

Sampling

Sample size determination: The sample size was determined using the following single population estimation formula:

$n= P (1-P)Z^2/d^2$

The following assumptions were used in determining the sample size:

- P – Taking the accuracy of Johnsons formula for estimation of fetal weight to be on average 68% [13, 14]
- Z=1.96 which is the standard normal variable at 95% confidence level
- d-is the margin of sampling error tolerated=5%: 334 mothers would be needed to give a precision of 5% around an observed percentage of estimated fetal weights correct to within 10% of the birth weight.
- n= 0.68x0.32x1.96x1.96/0.05x0.05=334

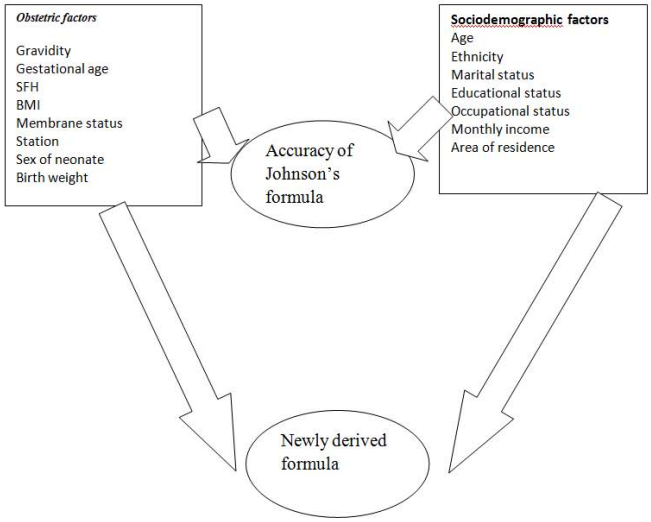
Sampling technique: All pregnant mothers who fulfil the inclusion and not in the exclusion criteria were involved during the period till the desired sample size was reached.

Research variables in the study

Dependent variable: Accuracy of Johnson's formula

Independent variables: Age, Ethnicity, Marital status, Occupation, Educational status, Annual income, Gravidity, Gestational age, Pre-pregnancy BMI, SFH, Membrane status, Station, Actual birth weight, Sex of neonate.

Conceptual-framework



Data Collection Instruments

Pretested structured interviewer administered questionnaire will be used to collect information on the socio demographic and obstetric factors.

Data collection

Women who met the criteria were recruited to participate in the study. Data collectors were residents assigned in the labour ward. Initially, verbal and written consent for inclusion in the study was obtained. Immediately after admission the data collectors record baseline data as shown on the datasheet.

The gestational age in our study was found by LNMP and early ultrasound. Pregnant mothers with unknown LMP were also involved because we can determine gestational age retrospectively after delivery by Ballard score.

Next pre delivery weight was taken.

Abdominal examination was done between contractions with the woman in the supine position. All mothers were asked to void before measurements are taken. The SFH was measured from the upper border of the pubic Symphysis to the highest point of the uterus. Measurement was made to the nearest 0.5cm. A soft non-flexible tape was used for measuring the SFH. Following this vaginal examination findings were recorded which included cervical dilation, station of the presenting part, membrane status. After delivery, the actual infant's weight was recorded. The birth weight was measured within 30 min after birth on the hospital baby scales by the resident. The author made frequent checks during the study to ensure that the scales are correctly zeroed and calibrated. Women's height was measured in standing position.

Data analysis

All data analysis was done using SPSS version- 20 statistical software. Descriptive statistics included calculations of means ± standard deviations, medians with ranges, and frequencies expressed as percentages with 95% confidence intervals. Absolute value of the difference between the EFW and the birth weight is calculated for each case and from this the mean weight

difference and the percentage error was calculated. Percentage error is calculated as the absolute weight difference divided by the birth weight, multiplied by 100. Percentage errors were also grouped as being within 10%, 20% or 30% of the birth weight. Percentage error within 10 % of the birth weight is considered accurate. Multivariable linear regression analysis between the actual birth weight and maternal sociodemographic and obstetric factors was done. Statistical significance was considered at P<0.05. Dummy tables were done for categorical variables.

Data quality control

Data collection format was pre-tested on 10% of the sample size out of study area in JUTH and necessary modifications were made. Participants who involved in the pre-test were excluded in the actual study analysis. Data collectors were trained for two days and every day the principal investigator checked the questionnaires for completeness and consistency.

Ethical Considerations

The proposal of this thesis was approved by Ethical clearance committee of College of health sciences of JU. Permission was taken from JUTH. Oral and written informed consent was obtained from every study participant before the interview by explaining the objective of the research. All the information collected from the study participants was handled confidentially through omitting their personal identification, and the data were used for the research purpose only.

RESULTS

Socio demographic characteristics

Three hundred thirty four pregnant mothers were included in the study. The majority of women are between the age groups of 21-30 years and the mean age was 25.0 ± 4.6 years; 96 % are married, 74% of them are Oromo in ethnicity, 42.2 % did not attend formal education, 54.5% were house wife. The mean maternal height was 160.4 ± 6.9 cm and the mean pre-pregnancy weight was 56.24 ± .9 kg. The mean BMI is 21.8 Kg/m^2. Two third (65.6%) of women have normal BMI while 15.3 % are under weight, 16.8% were overweight, while 2.4 % were obese. Sixty three percent were living in Jimma town while the rest were out of the town (Table 1).

Obstetric characteristics

Nearly half (49.7%) were primigravida, 76.3 % were at term and the mean gestational age was 39.3 ± 2.45 weeks, with a range of 28^{+2}-46 weeks. The average length of symphysis fundal height was 35.58 ± 2.96 cm with a range of 25 -46 cm. The fetal head was engaged in 111 cases (33.2%), and fetal membranes were ruptured in 234 (70%). The mean cervical dilatation at the time of examination was 4.5 ± 2.6 cm. Eighty eight percent have normal birth weight while 4.2 % have low birth weight and 7.5% are macrosomic. The mean birth weight was 3245.3 ± 51.8 g, with a range of 1400 -5000g (Table 2).

Prediction of birth weight using Johnson's formula

One hundred and twenty-six estimations (37.7%) were within 10% of the birth weight which is the level accepted as accurate (Table 3). Over all Johnson's formula over estimated in eighty eight percent and under estimated in twelve percent of the cases. The minimum weight difference of the entire sample was 0 and the maximum was 1540 gm with the mean absolute weight difference of 512 gm (Table 4). As shown in Table 5 the level of accuracy increases progressively as fetal weight increases and the accuracy is 0%, 38%, and 64 % in low birth weight, normal birth weight and macrosomic babies respectively. The formula tends to overestimate in all low birth weight infants, in 91 percent of normal birth weight and in 47 percent of macrosomia.

Table 1: Basic maternal socio-demographic characteristic of mothers who gave birth in JUTH, May-August 2014.

Socio-Demographic characteristics	Number	Percent
Age (years)		
<21	78	23.4
21– 25	114	34.1
26 – 30	109	32.6
31-35	24	7.2
36-40	8	2.4
>40	1	0.3
Marital status		
Married	311	93
Divorced	10	3
Single	8	2.4
Widowed	5	1.5
Ethnicity		
Oromo	247	74
Amhara	40	12
Gurage	16	4.8
Dawaro.	10	3
Yem	7	2.1
Tigrie	5	1.5
Others	9	2.7
Level of education		
Cannot read and write	88	26.3
Read and write only	63	18.9
Grade 1-4	24	7.2
Grade 5-10	86	25.5
Grade11-12	35	10.5
University/college	39	11.7
Occupation		
House wife	182	54.5
Civil servant	59	17.7
merchant	39	11.7
Farmer	33	9.9
Daily labourer	9	2.7
NGO	6	1.8
student	6	1.8
Annual income in ETH Birr		
<14400	73	21.8
14401_70000	253	75.7
>70000	8	2.5
BMI(kg/m2)		
<18.5	50	
18.5- 24.9	220	15.3
25-29.9	59	65.6
30-34.9	4	18.7
35-39.9	_	1.2
≥40	1	**.3**
Residence		
Jimma	212	63.5
Out of Jimma	112	36.5

Table 2: Obstetric characteristics of mothers who gave birth in JUTH, May-August 2014.

Obstetric characteristics	Number	Percent
Gravidity		
Primigravida	166	49.7
Multigravida	168	50.3
Gestational age at delivery (wks)		
<37	44	13.2
37-41^{+6}	255	76.3
≥42	35	10.5
Symphysis Fundal height(cm)		
25_30	44	13.1
31-37	245	73.7
≥38	45	13.2
Station		
-3	43	12.9
-2	86	25.7
-1	94	28.1
0	65	19.5
+1	31	9.3
+2	12	3.6
+3	3	0.9
Cervical dilatation		
0	14	4.2
1	14	4.2
2	48	14.4
3	55	16.5
4	68	20.4
5	33	9.9
6	34	10.2
7	7	2.1
8	19	5.7
9	5	1.5
10	37	11.1
Membrane status		
Ruptured	234	70.1
Intact	100	29.9
Birth weight (g)		
<2500	14	4.2
2,500-3999	295	88.3
≥4000	25	7.5
Sex of the neonate		
Male	**198**	59
Female	**136**	41

Table 3: Distribution of percentage error in estimation of fetal weight using Johnson's formula among pregnant mothers who gave birth in JUTH, may-august 2014.

Estimation	Percentage error	N	Percent	Total [N(%)]
Overestimation	≥30.0	51	15.27	295(88.3)
	20.0 – 29.9	74	22.16	
	10.1– 19.9	74	22.16	
	≤10	96	28.74	
Exact estimate	0	1	0.3	0.3
Underestimation	≤10	29	8.97	38(11.4)
	10.1 – 19.9	6	1.5	
	20.0 – 29.9	2	0.6	
	≥30.0	1	0.3	

Table 4: The range, minimum, maximum, mean, standard error of the mean and standard deviation of the absolute weight difference between the EFW and the birth weight among pregnant mothers who gave birth in JUTH, May-August 2014.

Sample size	Range	Mini-mum	maxi-mum	Mean	Stan-dard error of the mean	Stan-dard de-viation
334	1540	0	1540	512	19.4	356

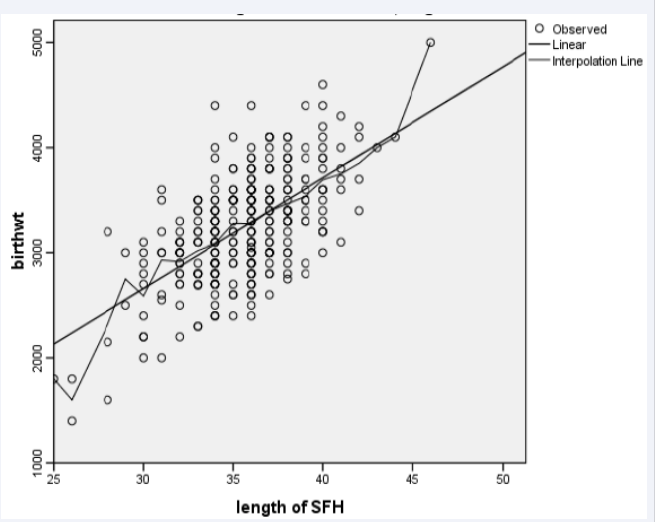


Figure 1 Scatter plot of actual birth weight and SFH among pregnant mothers who gave birth in JUSH, August 2014.

Derivation study

A regression model was built for ball maternal sociodemographic and obstetric factors as independent variables and birth weight as dependent variable after preparing dummy table for categorical variables. All variables were entered except Muslim, house wives, housemaids and government employs are excluded (Table 6).

Based on this the derived equation is:

EFW (gm) = -3124.333+103 (Gestatinal Age in week) +59(SFH in cm) +-155(membrane status) (1=intact, 0=ruptured membrane). R^2 = 0.623 and standard error =331.05

But inspection of the scatter plot in Figure 1 shows that the line is nearly linear between symphysis fundal height of 30cm and 43cm but this linear relationship is lost at the extremes. Considering the linear relationship at this two points only we can have a derivation formula based on for a linear equation y= y0(Y intercept) +slope of the graph(x). From the graph the mean actual birth weight at symphysis fundal height measurement of 30cm is 2600gm, that is y0 (Y intercept). Slope is calculated by taking the values at 2 points on the linear graph as (Y2-Y1)/X2-X1. From inspection of the graph the actual birth weight at symphysis fundal height value of 43 cm is 4100gm and at 30cm is 2600gm. So slope = (4100-2600) / (43-30) =115. Therefore the derived equation between these points is:

Estimated fetal weight (gm) = 2600 + 115(symphysis fundal height (cm) - 30).

DISCUSSION

Clinical methods of estimation of fetal weight have been shown to be as good as ultrasound at term, giving estimates that are correct to within 10% of the birth weight in 60% to 70% of case [6-8]. This study validated Johnson's formula. The formula provided intra partum prediction of birth weight in singleton live vertex presentations to within 10% of the birth weight in 37.7% of estimations. This value is very low when compared with to a similar validation study done Thailand and Brazil which have confirmed that Johnson's formula correctly predicts actual birth weight from 61 to 72 % [15-17]. While a similar study done in Ethiopia by Belete, and Gaym reported 38% accuracy [21]. This difference in the level of accuracy is because the Thailand and Brazil studies are done at term pregnancies and the other reason is there is difference in shape between Ethiopian pregnant women and Thailand and Brazilian populations (Table 7).

The accuracy in low birth weight, normal birth weight and macrosomic infants are 0 %, 37% and 64% respectively. Similarly the accuracy was significantly reduced as Symphysis fundal height decreases. Over all Johnson's formula over estimated in eighty eight percent of the cases .While it tends to overestimate in all low birth weight infants ,and in ninety one percent of normal birth weight infants, in fifty three percent of macrosomic infants it tends to under estimate. Therefore Johnson's formula accurately predicts birth weight in macrosomic babies.

This very low accuracy of Johnson's s formula to predict the birth weight can indicate that maternal socio-demographic and obstetric factors in addition to symphysis fundal height may affect the fetal weight estimation. On multivariable regression model gestational age at birth, symphysis fundal height value and status of the membrane are significantly associated with birth weight (Table 4: $R^2 = 0.62$, p-value = 0.00). This means the accuracy of our regression model to estimate fetal weight in our population is 62.3% similar to the accuracy of weight estimation by ultrasound. But this formula cannot be remembered easily so we have derived a linear equation which can be easily

Table 5: Frequency and percentage by accuracy and estimation values among baby weight classification of mothers who gave birth in JUTH, May-August 2014.

Birth weight (g)	Accuracy		Over estimation (%)	Exact estimation (%)	Under estimation (%)
	n	%			
< 2,500	0/18	0	100	0	0
2,500-4,000	110/291	37.8	91	0.3	9
> 4,000	16/25	64	47	0	53
Birth weight (g)	Accuracy		Over estimation (%)	Exact estimation (%)	Under estimation (%)
	n	%			
< 2,500	0/18	0	100	0	0
2,500-4,000	110/291	37.8	91	0.3	9
> 4,000	16/25	64	47	0	53

Table 6: Multivariable analysis of factors associated with infant birth weight among pregnant mothers who gave birth in JUTH, May-August 2014. (Dependent variable: neonatal weight).

Variable	B	Sign.	95.0% Confidence Interval for B	
			Lower bound	Upper Bound
(Constant)	-3124.333	.00	-4028.19	-2220.47
Length of SYMPHYSIS FUNDAL HEIGHT	59.64	.00	44.00	75.97
Gestational age in week	103	.00	85.25	121.66
Membrane status	-155.8	.001	-242.99	-67.29

EFW (gm) = -3124.333+103(Gestatinal age in week) +59(SFH in cm) - 155(membrane status) (1=intact, 0=ruptured membrane): ($R^2 = 0.62$, p-value = 0.00). Statistical significance at P≤0.05: B= Regression coefficient.

R	R Square	Adjusted R Square	Std. Error of the Estimate
.784	.623	.574	331.405

Regression model summary

Table 7: Summary of results of different studies done on accuracy of Johnsons formula.

Reference	Gestational age	Sample size	Overall Accuracy		<2500gm			2500-4000gm			>4000gm		
						Accuracy			Accuracy			Accuracy	
			N	%	N	n	%	N	n	%	N	n	%
Kumari 2010, India	Term	500	355	71	132		55	365	317	87	3	0	0
Amrita ,2004 India	Term	200	82	41	NOT AVAILABLE								
Nareelux ,India	28-42	126	45	35	6	1	17	117	42	36	3	2	67
Altenfelder,Brazil	term	132	80	61									
Watchree,Thailand	34-42	400	284	71	13	2	15	378	275	72	9	9	100

remembered by all levels of health professionals:

Estimated fetal weight (gm) = 2600 + 115(symphysis fundal height (cm) - 30).

CONCLUSION

Johnson's formula was found to be inaccurate in this study.

RECOMMENDATION

Johnson's formula should not be used for our community. We recommend using a simple clinical formula: Estimated fetal weight (gm) = 2600 + 115(symphysis fundal height (cm) - 30).

EFW (gm) = -3124.333+103(Gestatinal Age in week) +59(SFH in cm) +-155(membrane status) (1=intact, 0=ruptured membrane)

STRENGTHS AND LIMITATIONS

Strengths

1. The study was conducted between gestational ages of 28 to 46 weeks unlike others which limit their study at term.
2. The equation in predicting birth weight incorporated gestational age and membrane status other than SFH to predict birth weight which increases the accuracy of estimation nearly to ultrasound.

The main limitation of this study is that the SFH was measured by various health personnel. Therefore, it may cause measurement bias affecting validity of our study. However, those personnel were trained and qualified to do this task.

ACKNOWLEDGMENT

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