Maternal Physical Parameters for Predicting Neonatal Birthweight

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Background: *Estimating neonatal birthweight (NBW) is an essential part of labor management. Most rural hospitals in Thailand use symphysis-fundal height (SFH) to predict NBW, but the possibility of maternal and neonatal morbidities associated with incorrectly estimated extreme NBW remains a major problem.*
Objective: *To identify a formula for predicting NBW using maternal physical parameters in singleton pregnancies prior to delivery.*
Material and Method: *A cross-sectional study was performed of three hundred and ten singleton pregnant women who were assessed for maternal physical parameters during the 7-day period prior to delivery by a single researcher (Manovit. S). Pregnant women with non-vertex presentation, intrauterine death, or major structural or abnormal chromosomal fetuses were excluded. Parameters which were significantly related to NBW were evaluated using regression equations and formulae were constructed for predicting NBW.*
Results: *Five maternal physical parameters were significantly related to NBW: body weight (BW), height (Ht), symphysis-fundal height (SFH), back-fundal height (BFH), and transverse abdominal diameter (TAD). The most accurate formula in the present study was found to be EFW = (-21,062.57) + (0.97 x gestational age (weeks)^2) + (-0.06 x body weight (kg)^2) + (242.11 x height (cm)) + (-0.73 x height (cm)^2) + (39.13 x back-fundal height (cm)) + (0.94 x symphysis-fundal height (cm)^2) + (19.68 x transverse abdominal diameter (cm)). This formula showed a correlation of 0.674, absolute percentage error of 7.26% (SD, 5.71), 90.3% prediction within 15% of NBW, area under ROC curve of 0.90 for prediction of NBW ≥3,500 grams, sensitivity of 87.0% and specificity of 90.5% at a cutoff value of 3,226 grams.*
Conclusion: *This study proposes a novel formula for the prediction of NBW which might be very useful in evaluating parturients with large fetus in primary health care or low-resource settings.*

Keywords: *Neonatal birthweight, Maternal physical parameters, Symphysis-fundal height, Back-fundal height, Transverse abdominal diameter*

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Estimating neonatal birthweight (NBW) is an essential part of labor management. Diagnosis of macrosomic and low-birthweight fetuses can facilitate appropriate management and timely referral of diagnosed cases to suitable hospitals. Only secondary or tertiary hospitals in Thailand have access to ultrasound for diagnosis of macrosomic and low-birthweight fetuses, and most rural hospitals use clinical estimations or symphysis-fundal height (SFH) measurements to predict NBW.

Clinical estimations of NBW by palpation are as reliable as, or superior to, those estimated from ultrasonographic measurements of the fetus[1], except in cases of low birthweight and preterm neonates[2-4]; however, their accuracy depends on the experience of the individual obstetric care personnel[5]. To minimize the effect of this factor, most rural hospitals in Thailand use non-elastic tapes for measurement of SFH to estimate NBW with Johnson's formula because of its simplicity; nevertheless, the maternal and neonatal morbidities associated with extremely high NBW are still major problems.

The adverse consequences of excessive fetal growth are considerable. The rate of shoulder dystocia has been reported to be as high as 17% and 30% in neonates with birthweights of at least 4,500 and 5,000 grams, respectively[6], and significant neonatal neuromusculoskeletal injuries, and even mortality, can ensue. Maternal adverse events include postpartum hemorrhage, perineal laceration and infection; as a

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result, intrapartum diagnosis of macrosomia frequently leads to cesarean delivery to reduce the risks of failed vaginal delivery and shoulder dystocia[7,8].

The primary objective of this study of pregnant women who gave birth at Rajavithi Hospital was to determine the maternal physical parameters and factors including maternal age, gestational age, parity, current body weight, height, current body mass index (BMI), total weight gain, SFH, back-fundal height (BFH), transverse abdominal diameter (TAD) and fetal station which can be used to predict neonatal birthweight. The secondary objective was to develop a more accurate formula for estimating NBW using various maternal physical parameters.

Material and Method

The protocol of this research was reviewed and approved by the ethics committee of Rajavithi Hospital (No. 149/2557).

This cross-sectional study of term pregnant women (gestational age $37^{0/7}$-$41^{6/7}$ weeks) was conducted in the labor room of Rajavithi Hospital between 1st July 2014 and 28th February 2015. The inclusion criteria were singletons who had labor pain but whose membranes were intact and who delivered within 7 days of being enrolled. The exclusion criteria were fetal anomalies and non-vertex presentations.

Subjects who met the above criteria were admitted for vaginal or abdominal delivery. After informed consent was obtained, the background characteristics and antenatal record data were obtained. Vaginal examination was carried out to determine the fetal station and membrane status.

The patient was placed in the supine position. After the urinary bladder was emptied, and during uterine relaxation periods, SFH was measured in centimeters using a non-elastic tape from the highest point on the uterine fundus through the navel to the midpoint of the upper border of the symphysis pubis (Fig. 1A). BFH, the distance between the highest point of the uterus and the back of the pregnant woman, was measured in centimeters using a wood-made try square at the highest point of the uterus (Fig. 1B). TAD, the width of the maternal abdomen, was measured in centimeters using a wood-made try square to mark both sides of the maternal abdomen at the navel level (Fig. 1C). All subjects were measured by a single investigator (Manovit. S). Each measurement was made 3 times, using the tape reverse-side up, to the nearest centimeter after which the mean of the 3 readings was obtained.

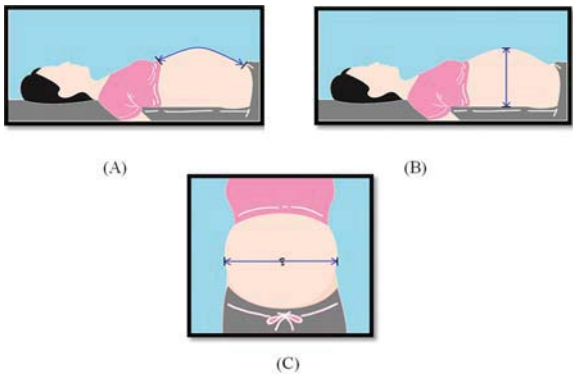

Fig. 1 Maternal abdominal measurements: (A) SFH measurement, (B) BFH measurement, and (C) TAD measurement.

The actual BW of the baby was measured in grams by the midwife on duty within one hour of birth using the same weighing scale. The midwives who weighed the babies were blind to the intrapartum estimates of NBW.

Sample size was calculated using a formula for estimating an infinite population proportion[9]. The proportion of 16% large-baby group (NBW ≥3,500 grams), based on statistics from Rajavithi Hospital's database, was used to calculate the required sample size with a 25% allowance for error of estimation. The calculated required sample number of about 310 pregnant women was recruited.

Statistical analysis of the data was carried out using SPSS for Windows, version 17. Demographic data were described as percentage, median, mean and standard deviation. Pearson's correlation coefficient was used to assess the correlation between NBW and maternal physical parameters. Multiple linear regressions were performed to estimate fetal weight using each equation. The predictive performance of each equation was then evaluated by calculating the area under the receiver operating characteristics curve (ROC-AUC) and its 95% confidence interval (CI), and the optimal cutoff values were identified. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) with 95% CI were also calculated. Statistical significance was set at a *p*-value of less than 0.05.

Results

Three hundred and ten pregnant women were enrolled in the present study. Clinical characteristics, maternal physical parameters, and the distribution of birthweight of the neonates are presented in Table 1.

Table 1. Clinical characteristics and maternal physical parameters

Characteristic/parameter	
Sex	
Male	155 (50.0)
Female	155 (50.0)
Maternal age (years)	27.45±6.26
Gestational age (weeks)	39.05±1.12
Parity, median (range)	2 (1-6)
Nulliparous	154 (49.7)
Multiparous	156 (50.3)
Current body weight (kilograms)	67.96±11.3
Height (centimeters)	156.18±6.22
Current body mass index (kilogram/meter^2)	27.84±4.18
Total weight gain (kilograms)	14.42±5.27
Symphysis-Fundal height (centimeters)	35.88±2.54
Back-fundal height (centimeters)	26.92±2.27
Transverse abdominal diameter (centimeters)	35.01±3.12
Fetal station	-1 (-3-2)
Cervical dilatation (centimeters)	3 (1-10)
Effacement (percentage)	70 (10-100)
Vaginal delivery	213 (68.7)
Vacuum/forceps extraction	11 (3.6)
Cesarean delivery	86 (27.7)
Placenta weight (grams)	621.97±117.91
Neonatal birthweight (grams)	3,140.00±378.43
<2,500 grams	10 (3.2)
2,500 to 3,499 grams	246 (79.4)
≥3,500 grams	54 (17.4)

Values are presented as n(%), mean ± SD, and median (range)

Because the number of neonates weighing more than 4,000 grams was inadequate, those weighing ≥3,500 grams were included in the large-baby group.

Linear correlations found between maternal physical parameters and neonatal birthweight are shown in Table 2. Nine significant variables were related to neonatal birthweight ($p<0.05$): maternal age, gestational age, current weight, weight gain throughout pregnancy, height, current body mass index, symphysis-fundal height, back-fundal height and transverse abdominal diameter.

Eight highly significant variables were introduced into the analysis of the polynomial regression equations. These four equations yielded decision coefficients ranging from 0.657 to 0.677, as shown in Table 3. It was found that the equations with the highest decision coefficients were equations 3 and 4.

Performance diagnostics of the EFW equations in the prediction of NBW are shown in Table 4. The lowest absolute percentage errors were 7.26 and 7.25 in the EFW3 and EFW4 equations, respectively. Percentage predictions within 10% and 15% were lowest in EFW4 equations, while at the 95% confidence level (95% limit of agreement), EFW3 and EFW4 were the best equations.

To predict the possibility of shoulder dystocia, which usually occurs in larger neonates, the diagnostic efficiency of each EFW equation in the prediction of NBW ≥3,500 grams was calculated, and the results are shown in Table 5. The sensitivity, specificity, and positive and negative predictive values were highest in the EFW3 equation at 87.0%, 90.5%, 66.2%, and 97.1% respectively at a cut off value of 3,226 grams. The correlation between actual NBW and estimated fetal weight calculated by the EFW3 equation is shown as a scatter diagram in Fig. 2.

Discussion

In keeping with the results of most earlier

Table 2. Linear correlation between maternal physical parameters and neonatal birthweight

Parameters	Pearson correlation	*p*-value
Age	0.136	0.016*
Parity (nulli- vs. multi-)	0.015	0.797
Gestational age	0.315	<0.001*
Current body weight	0.352	<0.001*
Height	0.203	<0.001*
Current body mass index	0.286	<0.001*
Total weight gain	0.228	<0.001*
Symphysis-Fundal height	0.560	<0.001*
Back-Fundal height	0.406	<0.001*
Transverse abdominal diameter	0.340	<0.001*
Fetal station, median	0.016	0.777
Cervical dilatation	0.020	0.720
Cervical effacement	0.026	0.649

* Statistical significance at *p*-value <0.05

Table 3. Comparison of various estimating fetal weight (EFW) equations in relation to NBW

EFW	Regression equation	R	R^2	Mean difference		
				%	(95%CI)	*p*-value
EFW1	(-18412) + (0.9*GA^2) + (25*BW) + (-0.2*BW^2) + (218*Ht) + (-0.7*Ht^2) + (1.1*SFH^2)	0.657	0.432	5.2	(-26.7,37.0)	0.750
EFW2	(-5964) + (79*GA) + (-8.9*BW) + (15*Ht) + (40.7*BFH) + (66.6*SFH) + (21.9*TAD)	0.665	0.442	0.0	(-31.6,31.6)	1.000
EFW3	(-21062) + (0.9*GA^2) + (-0.1*BW^2) + (242*Ht) + (-0.7*Ht^2) + (39*BFH) + (0.9*SFH^2) + (19.7*TAD)	0.674	0.455	4.2	(-27.0,35.4)	0.791
EFW4	(-21846) + (75*GA) + (-0.1*BW^2) + (242*Ht) + (-0.7*Ht^2) + (38.5*BFH) + (-0.7*TAD^2) + (1.9*SFH*TAD)	0.677	0.458	-7.0	(-38.1,24.2)	0.660

Table 4. Diagnostic performance of the EFW equations in the prediction of NBW

Regression equation	Absolute percentage error (%)	Predictions within 10% (%)	Predictions within 15% (%)	95% Limit of agreement
EFW1	7.45±5.89	73.2	91.3	-553.8, 565.0
EFW2	7.31±5.80	76.8	90.6	-554.3, 554.2
EFW3	7.26±5.71	74.5	90.3	-551.8, 543.4
EFW4	7.25±5.77	73.2	91.0	-538.9, 552.9

Values are present as mean ± SD, percentage (%)

research[7], the present study found that gestational age, current weight, weight gain, height, and current body mass index contributed to differences in NBW; however, parity and fetal station were not independent

predictors of NBW. This may be because of differences in fetal station assessment, levels of parity and sample size.

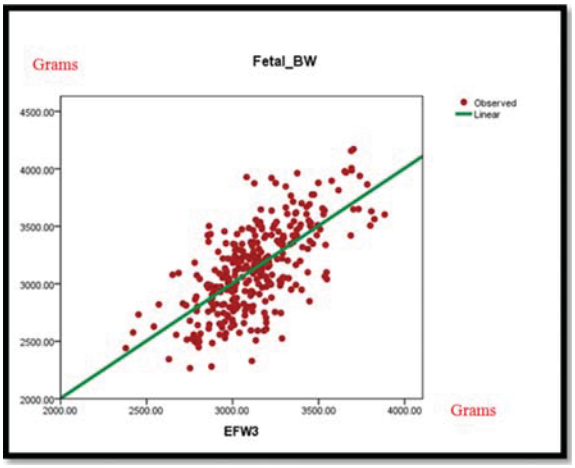

Fig. 2 Correlation between neonatal birthweight and estimated fetal weight by EFW3 equation.

When Johnson's formula was used with the data, the rate of prediction within 10% of actual neonatal birthweight for Thai parturients was 34.8%. This was similar to that found (35.71%) in Nareelux's study[10] but much lower than the 72% revealed in Numprasert's study[11].

Two additional maternal abdominal diameters, BFH and TAD, are valuable in predicting NBW. Using the EFW3 formula, the rate of prediction within 10% increased to 74.5% compared to the 68.1% found using the formula of Buchmann[12]. The EFW3 formula yielded a coefficient of multiple correlation of 0.67 compared to 0.56, 0.73 and 0.57 found in the studies of Mortazavi, Woo and Kraiem, respectively, which used SFH and maternal abdominal girth to estimate NBW[13-15]. Compared with other studies that used clinical estimations of NBW in term pregnant women (gestational age ≥37 weeks)[16-20], this new formula demonstrated the lowest mean absolute percentage errors and highest rate of prediction within 10% of actual neonatal birthweight, as shown in Table 6.

Table 5. Diagnostic efficiency of the EFW equations in the prediction of NBW ≥3,500 grams

Birthweight ≥3,500 gm	ROC		Cutoff value (grams)	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV %	NPV %
	AUC	(95%CI)					
EFW1	0.89	(0.84 to 0.94)	3,259	85.2 (84.0 to 86.4)	82.8 (72.8 to 92.8)	51.1	96.4
EFW2	0.89	(0.85 to 0.94)	3,230	87.0 (78.1 to 95.9)	77.3 (66.2 to 88.4)	44.8	96.6
EFW3	0.90	(0.85 to 0.94)	3,226	87.0 (78.1 to 95.9)	90.5 (82.7 to 98.3)	66.2	97.1
EFW4	0.90	(0.85 to 0.94)	3,236	87.0 (78.1 to 95.9)	79.7 (69.0 to 90.4)	47.5	96.7

Table 6. Studies comparing clinical estimated fetal weight of gestational age ≥37 weeks

Reference	No. of patients	Birthweight (grams)	Method of estimation	Mean absolute % error	Predictions within 10%
Watson 1988 [15]	100	2,280 to 4,650	Clinical	8.2%	66.0%
Chauhan 1992 [16]	106	2,440 to 5,225	Clinical	9.0%	66.0%
Chauhan 1993 [17]	200	2,440 to 5,225	Clinical	9.1%	65.0%
Fox 2008 [18]	187	3,373±479	Clinical	8.6%	68.5%
Kayem 2009 [19]	1689	N/A	FH	11.1%	56.7%
			FH+	9.6%	61.6%
The present study	310	3140±378.4	FH+	7.26%	74.5%

FH = Use only fundal height measurement in equation
FH+ = Use fundal height measurement and other maternal parameters in equation

With regard to predictions of the large-baby group (NBW ≥3,500 grams), the sensitivity, specificity, positive and negative predictive value of this formula were 87.0%, 90.5%, 66.2%, and 97.1%, respectively. These results fell in the upper range of accuracy of clinical estimates in NBW studies[13,20,21], as shown in Table 7.

Finally, compared with other methods used to predict NBW[22], this new maternal characteristic prediction equation yielded a good correlation coefficient with actual NBW, mean absolute percentage error, and rate of prediction within 15% of actual NBW, as shown in Table 8.

In the present study, all data were collected by a single investigator (MS) which eliminated inter-observer variation. The same device was used to measure each parameter, which reduced measurement deviation. The present study had many limitations, however, including: 1) lack of validation of the formula; 2) its limited usefulness for prediction of macrosomic infants who weigh more than 4,000 grams; and 3) its inability to give information about preterm babies with gestational age of less than 37 weeks.

Conclusion

As maternal abdominal diameter appears to reflect uterine volume, it can be useful in adding value to predictions of NBW in term pregnant women. The present study has shown that the EFW3 formula predicted the NBW with an error of less than 15% in 90.3% of cases. Further studies are necessary, using larger numbers of pregnant women, to assess its validity and accuracy in predictions for infants weighing more than 4,000 grams. It would be more convenient and useful to use a computer-assisted program to calculate EFW with this formula.

What is already known on this topic?

Most rural hospitals use clinical estimations or symphysis-fundal height (SFH) measurements in conjunction with Johnson's formula to predict NBW, but the potential for maternal and neonatal morbidities associated with incorrect estimations of extreme NBW remains a major problem.

What this study adds?

This study proposes a novel formula using various maternal physical parameters for estimation of neonatal birthweight. It might be very useful for evaluation of parturients with large fetuses in low-resource hospital settings in order to provide better-

Table 7. Studies comparing clinical estimated fetal weight of large-baby group

Reference	No. of patients	NBW (grams)	Method of estimation	Cut-off (grams)	Sen%(95% CI)	Spec%(95% CI)	PPV %	NPV%
Khani[19]	8	>4,000	Clinical	NA	33.5 (1.5 to 65.5)	98.2 (89.0 to 100.0)	57.1	95.2
			Johnson	NA	75.0 (45 to 100.0)	98.8 (91.3 to 100.0)	75.0	98.8
Kayem[20]	124	≥4,000	FH	3,818	37.1 (28.6 to 45.6)	95.0 (91.2 to 98.8)	36.8	95.0
			FH+	3,710	45.1 (36.4 to 53.8)	95.0 (91.2 to 98.8)	41.5	94.6
Mortazavi[12]	27	>4,000	FH	3,450	75.0 (58.7 to 91.3)	85.4 (79.2 to 91.6)	99.4	95.0
			FH+AG	3,900	81.3 (66.6 to 96.0)	82.2 (79.2 to 91.6)	99.5	86.0
The present study	54	≥3,500	FH+	3,226	87.0 (78.1 to 95.9)	90.5 (82.7 to 98.3)	66.2	97.1

NBW = Neonatal birthweight; Sen = Sensitivity; Spec = Specificity; PPV = Positive predictive value; NPV = Negative predictive value; FH = Use only fundal height measurement in equation; FH+ = Use fundal height measurement and other maternal parameters in equation; FH+AG = Use fundal height and abdominal girth measurements in equation

Table 8. Comparison of results from methods of predicting term birthweight. (modified from Nahum GG.)[22]

Method	Correlation coefficient with actual NBW	Mean absolute percentage error (%)	Predictions within 15% of actual NBW (%)
Clinical estimation			
Leopold maneuvers	0.60	9.9	83
Maternal characteristics prediction equation	0.55	9.8	86
This study's equation	0.674	7.26	90.3
Ultrasonographic estimation			
Hadlock equation 1	0.61	8.4	88
Combs equation	0.60	8.3	82
Hadlock equation 3	0.60	9.4	83
Hadlock equation 2	0.58	9.4	78
Campbell equation	0.42	10.3	79
Wars of equation 2	0.63	10.3	61
Wars of equation 1	0.40	10.9	72
Shepard equation	0.52	11.4	63

planned intrapartum care.

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Potential conflict of interest

None.

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