

## INTEGRATION OF FETAL MID THIGH SOFT TISSUE THICKNESS IN ULTRASOUND BIRTH WEIGHT ESTIMATION FORMULA INCREASES THE ACCURACY OF FETAL WEIGHT ESTIMATION NEAR TERM

SHRIPAD HEBBAR\*, SUKRITI MALAVIYA, SUNANDA BHARATNUR

Department of Obstetrics and Gynaecology, Kasturba Medical College, Manipal Academy of Higher Education, Manipal – 576 104, Karnataka, India. Email: drshripadhebbbar@yahoo.co.in

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### ABSTRACT

**Objective:** The objective of the study was to find whether incorporation of MTSTT in fetal weight estimation formulae which are traditionally based on biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) improves birth weight (BW) estimation.

**Methods:** In a prospective observational study, MTSTT was measured within 1 week of delivery in 100 women with term singleton pregnancy along with other standard biometric parameters, i.e. BPD, HC, AC and FL, and MTSTT. Multiple regression analysis was carried out using PHOEBE regression software using different combinations of biometric variables to find out the best fit model of fetal weight estimation. The predicted BW was compared with actual neonatal BW soon after delivery and regression coefficients ( $R^2$ ) were determined for each of prediction models for comparing the accuracies.

**Results:** Mean gestational age at delivery was  $38.4 \pm 1.08$  weeks and the BW of neonates varied between 2.18 kg and 4.38 kg (mean  $\pm$  standard deviation:  $3.07 \pm 0.43$  kg). By adding MTSTT to BPD, HC, AC, and FL, we obtained the formula  $\text{Log}_{10}(\text{BW}) = -0.14783 + 0.00725 * \text{BPD} + 0.00043 * \text{HC} + 0.00436 * \text{AC} + 0.01942 * \text{FL} + 0.16299 * \text{MTSTT}$ , which had a very good Pearson regression coefficient ( $r^2: 0.89$   $p < 0.001$ ) compared to conventional models based on standard fetal biometry. All prediction models had better strength of correlation when combined with MTSTT ( $p < 0.001$ ). The routine four parameter formula could identify 45% and 80% of fetuses within 5% and 10% weight range; pick up rate was further increased to 61% and 95% by addition of MTSTT.

**Conclusion:** It is evident that addition of MTSTT to other biometric variables in models of fetal weight estimation improves neonatal BW prediction ( $r^2=0.89$ ).

**Keywords:** Fetal weight, Mid-thigh soft-tissue thickness, Ultrasonography.

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### INTRODUCTION

In modern obstetrics appropriate knowledge of fetal weight before planning mode of delivery is of utmost importance and it is well-known that allowing vaginal delivery in undiagnosed fetopelvic proportion may be associated with higher incidence of maternal and neonatal morbidity such as reproductive trauma and birth injuries due to problems associated with the second stages such as instrumental delivery, shoulder dystocia and birth trauma leading significant and long-term problems both in mother and the neonate [1-3].

In low resource settings, the only way to determine approximate before birth is clinical estimation using different formulae based on measurements of symphysis fundal height [4,5], abdominal girth [6], and station of fetal head [7]. However, these methods are associated with estimation errors somewhere between 10 and 20% [8,9], of the actual birth weight (BW), which can be either underestimation or overestimation. Underestimation of the potentially large baby is associated with labor abnormalities such as prolonged active phase, protracted descent of the presenting part, and shoulder dystocia, whereas overestimation of the small-sized baby may lead to iatrogenic premature delivery and neonatal problems due to low BW [10,11]. This suggests that accurate BW estimation is necessary to limit the complications associated with both undersized and oversized fetuses.

Since the advent of ultrasound in obstetrics by Prof. Ian Donald [12], the fetal weight estimation has been revolutionized, and ample of information is available on this aspect of ultrasound practice [13].

Now it is possible to measure various fetal biometric parameters such as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) and multiple formulae have been derived by regression analysis with various accuracies both in low BW and macrosomic babies [14-16]. These biometric measurements are based on linear or planar measurements of in utero fetal sections, and definite guidelines have been laid down about measurement techniques [17]. Ideally, a BW estimation formula should have least systematic and random errors with at least 90% correlation. However, due to biological, ethical, regional and many other unknown factors, at present, it appears that ultrasound formulae using conventional biometric parameters have reached their diagnostic limits. This indicates that there is a need for additional parameters to improve accuracy BW prediction models [18,19].

The value of mid-arm circumference is well known in neonatology to screen for low BW babies [20]. This can be extrapolated to intrauterine measurement of body fat areas such as mid-thigh mass, abdominal fat mass, subscapular fat, and cheek-to-cheek diameter [21,22]. Studies have proved that extent of subcutaneous fat distribution also influences the

fetal weight and incorporating fat thickness in ultrasound formulae greatly increases the accuracy of antenatal determination of expected BW [23-26].

Among soft tissue dimensions, measurement of mid-thigh soft-tissue thickness (MTSTT) is gaining considerable attention among researchers and but there are very few Indian studies in this context [27-29]. The present study examines the role of adding MTSTT to conventional biometric parameters in regression equations and whether this can improve the ultrasound-based fetal BW prediction models.

**METHODS**

This prospective cross-sectional study was conducted in the Department of Obstetrics and Gynaecology from a tertiary referral hospital between August 2013 and August 2015. The study was approved by Institutional Ethical Committee, and all the patients gave informed consent. The study population included singleton term patient with a scan done within a week of delivery between 37 and 40 weeks. Pregnancies with multiple gestations, fetuses with congenital anomalies were excluded from the study. Pregnancy complications such as preeclampsia and gestational diabetes mellitus were not exclusion criteria unless congenital anomalies in the fetus. Sample size estimation was done using the model;

$N = 50+8K$ ,

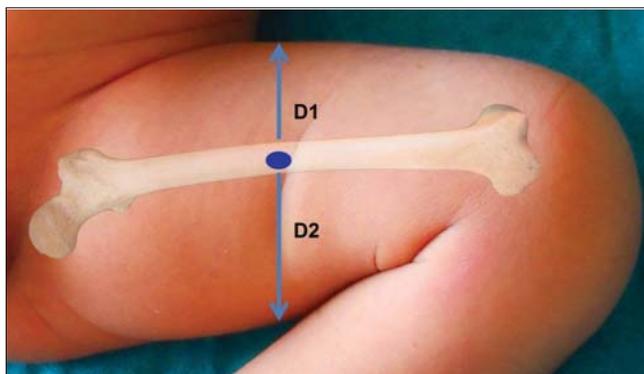
Where in N is the number of patients required and K is the number of independent variables.

According to the above formulae, the sample size was calculated as a minimum of 98. Our sample size of 100 was thus more than enough to derive statistically significant results.

The sonographic examination was performed by the first author using ultrasonography Machine with a 3.5 MHz probe (Philips HD11XE) and. BPD, HC, AC, and FL was assessed by standard methods [30]. Using sliding and rotatory movements the entire length of the femur was captured along with thigh outer borders making sure that the image occupied at least 75% of the screen (Figs. 1 and 2). We defined MTSTT as thickness of the vastus lateralis muscle including adipose tissue right up to skin margin at the level of mid femur. Both thicknesses (superior and inferior to mid femur) were obtained and average of these measurements was considered for calculation of MTSTT. Actual BW also was measured immediately after birth.

**Statistical analysis**

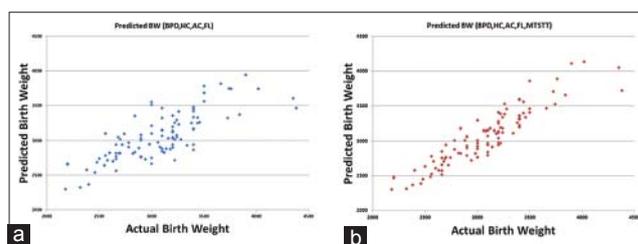
To find the best fit model for predicting BW, different combinations of ultrasound biometric parameters were analyzed by PHOEBE regression software. We used cm as a unit for these biometric variables, and BW was expressed in kilogram (kg). As BW distribution did not follow normal distribution, we used various transformations to fit the BW distribution curve to near normality using Kolmogorov Smirnov test. Log transformation of BW was found to fit normality rules, and hence Log 10 (BW) was used for prediction of BW. Regression coefficients ( $R^2$ ) were determined for each of prediction models for comparing the accuracies.



**Fig. 1: Principle of measurement**



**Fig. 2: Actual measurement**



**Fig. 3: (a and b) Scattered diagrams for birth prediction model accuracies using four standard biometric parameters ( $R^2: 0.65, <0.001$ ) as in figure on the left side. Right side figure shows addition mid-thigh soft-tissue thickness to four standard parameters further improves neonatal birth weight assessment ( $R: 0.89, p<0.001$ )**

**Table 1: Demographic and obstetric characteristics of the study population (n=100)**

| Parameters                | Observation     |
|---------------------------|-----------------|
| Maternal age (mean±SD)    | 28.4±4.025      |
| Primipara                 | 62              |
| Multipara                 | 38              |
| Gestational age (mean±SD) | 38.4±1.08       |
| *Fetal sex                |                 |
| Male                      | 46              |
| Female                    | 54              |
| BW                        |                 |
| Min                       | 2180            |
| Max                       | 4380            |
| Mean±SD                   | 3071.45±430.019 |

\*Gender checked after delivery. SD: Standard deviation, BW: Birth weight

**Table 2: Descriptive statistics of ultrasonic variables (in cm) in term pregnancy (n=100)**

| Parameter | Mean±SD        | Minimum | Maximum |
|-----------|----------------|---------|---------|
| BPD       | 9.2155±0.3984  | 8.31    | 10.2    |
| HC        | 32.974±1.3412  | 28.8    | 36.1    |
| AC        | 33.055±1.9194  | 27.9    | 38.3    |
| FL        | 7.2664±0.37477 | 6.1     | 8.4     |
| MTSTT     | 1.6224±0.26849 | 1.08    | 2.28    |

BPD: Biparietal diameter, HC: Head circumference, AC: Abdominal circumference, FL: Femur length, MTSTT: Mid-thigh soft-tissue thickness, SD: Standard deviation

**RESULTS**

Table 1 summarizes demographic characteristics of the patients studied. Mean ± standard deviation (SD) for mothers' age was 28.4±4.025 years. Mean gestational age at delivery was found to be 38.4±1.08 weeks and

Table 3: Descriptive statistic of ultrasonic variables in term pregnancy (n=100)

| Variables              | Predictive formulae   | R <sup>2</sup> |
|------------------------|---|----------------|
| BPD, AC                | Log10(BW)=-0.40925+0.02251*BPD+0.02072*AC                                     | 0.55           |
| BPD, AC, MTSTT         | Log10(BW)=-0.05752+0.01037*BPD+0.00492*AC+0.17401*MTSTT                       | 0.84           |
| BPD, FL                | Log10(BW)=-0.53585+0.04803*BPD+0.07931*FL                                     | 0.45           |
| BPD, FL, MTSTT         | Log10(BW)=-0.09193+0.01367*BPD+0.02162*FL+0.17988*MTSTT                       | 0.85           |
| BPD, AC, FL            | Log10(BW)=-0.57899+0.0147*BPD+0.01678*AC+0.0512*FL                            | 0.63           |
| BPD, AC, FL, MTSTT     | Log10(BW)=-0.14548+0.00815*BPD+0.00442*AC+0.01969*FL+0.16279*MTSTT            | 0.86           |
| BPD, HC, AC, FL        | Log10(BW)=-0.55881+0.02089*BPD-0.003*HC+0.01709*AC+0.0528*FL                  | 0.65           |
| BPD, HC, AC, FL, MTSTT | Log10(BW)=-0.14783+0.00725*BPD+0.00043*HC+0.00436*AC+0.01942*FL+0.16299*MTSTT | 0.89           |

BPD: Biparietal diameter; HC: Head circumference; AC: Abdominal circumference; FL: Femur length; MTSTT: Mid-thigh soft-tissue thickness; BW: Birth weight

majorities were primigravida. The BW of neonates varied between 2.18 Kg and 4.38 Kg (mean  $\pm$  SD: 3.07 $\pm$ 0.43 kg).

Descriptive statistics of five major ultrasound biometric parameters are shown in Table 2. All measurements are given in cm. BPD, HC, AC, and FL measurements are approximately same as term (37–40 weeks) measurements. Mean  $\pm$  SD for the new parameter (MTSTT) was 1.62 $\pm$ 0.26 cm.

Predictive BW formulas derived by PHOBE linear regression software are illustrated in Table 3. It can be seen that addition of MTSTT to any combinations of standard biometric parameters improve the correlation statistics significantly ( $p=0.001$ ) and when MTSTT measurement is added to all four major parameters (BPD, HC, AC, and FL) the maximum R<sup>2</sup> values (0.89) can be achieved. The conventional four parameter formula could identify 45% and 80% of fetuses within 5% and 10% weight range; pick up rate was further increased to 61% and 95% by addition of MTSTT.

Fig. 3a and b are the scattered diagrams showing a correlation between actual BW and predicted BW on x- and y-axis. It can be understood that by adding MTSTT the dispersion of the actual and predicted BW can be reduced and thereby demonstrating their closeness.

## DISCUSSION

The importance of fetal weight estimation in planning the optimal route of delivery in obstetric care cannot be underestimated. The conventional formulae adopted by modern ultrasound machines still are based on the Hadlock formula which was invented in the early 90s [14,17]. Even with careful and repeated measurements, ultrasonically estimated BW can differ from actual BW by 10%-15%. This is because neonatal body weight is influenced by soft tissue distribution and by incorporating those into traditional formulae may decrease these errors [22].

Many studies have focused on improvisation of BW prediction models by adding subcutaneous fat thickness. Foromouzmehr *et al.* showed a linear relation between abdominal fat and BW in babies of all weight ranges and this association was present even when the ultrasound estimation of weight was performed within 11 days of delivery [31]. Several studies have focused on the role of abdominal fat thickness in predicting macrosomic babies in pregnancies complicated by gestational diabetes [32,33]. Higgins *et al.* found that anterior abdominal wall thickness in large babies was significantly more compared to normal babies [34]. They opined that if this thickness is >5.6 mm, along with AC >90<sup>th</sup> centile, the obstetrician should be alerted as the baby may have macrosomia.

However, these studies have focused only on fat distribution, but even the muscle mass will contribute to the overall weight of the baby. Extensive studies done by Bernstein and coworkers have shown that both lean (muscle) mass, as well as a fat mass, are related to fetal growth right from the beginning of the second trimester and exhibit a unique pattern especially in diabetic pregnancies [35,36]. It was the novel idea of Scioscia *et al.* (2008) who proposed that femoral soft tissue thickness can be used as a potential marker of BW [37]. They also proved that MTSTT can replace AC measurements whenever there is a technical difficulty to obtain correct plane for fetal abdominal

transverse section [38]. They further extended their study in the prediction of macrosomia and opined that only linear measurements (including femur soft tissue thickness) are good enough to estimate large BW [28]. An Iranian study showed adding mid-thigh tissue parameters to conventional biometric formula improves the accuracy of BW prediction (R<sup>2</sup>=0.77) [27]. An Egyptian study too found association between fetal thigh measurements and actual BW (MTSTT-R<sup>2</sup>=0.656,  $p<0.001$ ), FL-R<sup>2</sup>=0.573,  $p<0.001$ ), BPD-R<sup>2</sup>=0.250,  $p<0.001$ ), and AC-R<sup>2</sup>=0.310,  $p<0.001$ ) [29].

Although it appears that MTSTT can be effective replacement for difficult AC measurements, there may be situations where dimensional assessment fetal thigh may be technically impossible as in cases of breech presentations. However, this particular presentation contributes for only 3% of fetal presentations, and still MTSTT can be used in rest of 97% of presentations [27]. The value of MTSTT in predicting fetal weight in preterm fetuses, multifetal gestation, hypertensive disorders of pregnancy [39], and thyroid disorders [40] has still to be explored. MTSTT can be useful in the evaluation of intrauterine growth restriction along with Doppler study and umbilical cord morphology to assess the fetal weight and neonatal outcome [41,42].

## CONCLUSION

MTSTT being a linear measurement is easy to obtain, simple and accurate and can be added to standard biometric parameters to improve fetal weight estimation by ultrasound at term before delivery. These findings suggest that establishment of gestational age-specific MTSTT ranges and incorporating them into intrauterine growth charts at sequential ultrasound scans may help in identifying the disorders of fetal growth.

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