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A PROSPECTIVE STUDY ON BIRTH WEIGHT ESTIMATION OF FETUS USING SONOGRAPHIC MEASUREMENTS SUCH AS MID-THIGH SOFT TISSUE THICKNESS & FETAL BIOMETRY

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ABSTRACT

Accurate fetal weight estimation is essential for identifying abnormal fetal growth and guiding obstetric management. Conventional ultrasound-based methods primarily rely on fetal biometric parameters but may not fully reflect fetal body composition. Mid-thigh soft tissue thickness (MTSTT) has emerged as a potential adjunctive parameter for improving fetal weight estimation. This prospective observational study aimed to evaluate the correlation between antenatal fetal biometry, mid-thigh soft tissue thickness, and actual birth weight (ABW), and to assess the utility of mid-thigh soft tissue thickness in fetal weight prediction. A total of 90 pregnant women with singleton pregnancies between 34 and 40 weeks of gestation were included. Ultrasound measurements of biparietal diameter (BPD), abdominal circumference (AC), femur length (FL), and mid-thigh soft tissue thickness were obtained. Estimated fetal weight was assessed using conventional biometric parameters and mid-thigh soft tissue thickness-based methods, while ABW was recorded immediately after delivery. Data were analyzed using SPSS version 23. All evaluated sonographic parameters demonstrated significant positive correlations with birth weight. Abdominal circumference showed the strongest correlation, followed by femur length, biparietal diameter, and mid-thigh soft tissue thickness. The regression model incorporating biparietal diameter, abdominal circumference, femur length, and mid-thigh soft tissue thickness demonstrated substantial predictive ability ($R^2 = 0.76$). These findings indicate that mid-thigh soft tissue thickness T provides additional information regarding fetal body composition and enhances fetal weight prediction when combined with conventional biometric measurements. Mid-thigh soft tissue thickness may enhance fetal weight estimation and obstetric decision-making.

KEYWORDS: Birth weight; Fetal biometry; Mid-thigh soft tissue thickness; Ultrasonography; Fetal weight estimation.

1. INTRODUCTION

Foetal growth assessment is a crucial component of contemporary prenatal care and is necessary for accurate diagnosis. Birth weight is a critical measure of the well-being of the newborn and is closely related to perinatal morbidity and mortality. Abnormal fetal growth patterns such as growth restriction and excess fetal growth may contribute to poor maternal and fetal outcomes. Thus, a reliable estimate of fetal weight during pregnancy is important to recognize high-risk pregnancies and provide proper management of the obstetric process. For fetal assessment, ultrasonography is the most commonly used imaging tool as it is safe, non-invasive and easily accessible. Biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) are biometric measurements used in traditional sonographic foetal growth assessment. These measurements are used in popular foetal weight estimation formulas.

Throughout pregnancy, weight of fetal estimate is a significant factor in clinical decision making. Information on predicted birth weight can aid in detecting fetuses with abnormal growth and assist in the management of monitoring, delivery timing and delivery mode. Fetal weight estimation is especially crucial in minimizing the complications of low birth weight, fetal macrosomia, birth trauma and operative delivery. Although obstetric ultrasonography has improved, in general, the most accurate assessment of weight of fetal is still difficult to obtain. Consequently, other sonographic features are increasingly being sought that can contribute to the prediction of accuracy. In recent investigations, body composition of fetus and soft tissue assessment has been included, as it can give information that goes beyond just the skeletal measurements (Warska et al., 2018).

Traditional fetal biometry is frequently used in clinical practice, but some drawbacks have been noted. The majority of formulas have been developed based on skeletal measurements and may not be representative of differences in fetal adiposity and fetal body composition. Therefore, there is a risk of prediction errors, especially at the extremes of weight ranges in fetuses. Furthermore, the accuracy of traditional biometric measurements may be affected by the fetal position, gestational age, and operator factors. These restrictions indicate that skeletal growth may not be a complete indicator of the overall growth and nutritional status of the foetus. This has led to a growing focus on the use of soft-tissue measurements in fetal weight estimation models, as a way to enhance predictive accuracy.

The fetal soft-tissue assessment has become a useful measurement supporting traditional sonographic biometry. Soft tissue measurements give information about fetal nutritional status, accumulation of adipose tissue and body composition unlike skeletal parameters. A few studies have shown that the sonographic evaluation of fetal soft tissues is a useful tool in fetal growth assessment and birth weight estimation (Warska et al., 2018). The measurements of subcutaneous tissue in fetuses using a third trimester ultrasound were related to birth weight and could be clinically useful in the prediction of fetal growth, as reported by Yang et al. (2019). In the same way, Aliyeva and Aydın (2021) showed the usefulness of the soft-tissue evaluation in the process of fetal weight estimation based on ultrasonographic evaluation. Some other techniques such as fetal thigh volume measurements have also been found to be useful as indicators of fetal growth and prediction of fetal weight (Egong et al., 2026).

Since several parameters of soft tissue thickness have been studied, the mid-thigh soft tissue thickness (MTSTT) has been the one that has been the most discussed due to its simplicity, reproducibility, and clinical applicability. The fetal thigh is a good location for fetal body composition measurements because it is highly composed of muscle and adipose tissue. MTSTT has the ability to directly inform on peripheral soft tissue accumulations and may be used in conjunction with regular biometric measurements. Hebbar et al. (2018) showed the improvement in the accuracy of the fetal weight estimation formulas when the MTSTT was also included. Hassanein et al (2023) also reported that MTSTT was found to be significantly related to fetal weight and could be useful along with other sonographic parameters to estimate fetal weight. Adarsh et al. (2020) proposed that MTSTT could be a substitute for the traditional methods because of its supremacy in predicting the fetal weight. Similarly, Mohammed et al. (2022) found that there was a strong association between soft-tissue thickness of the thigh and birth weight. Recently, Salman et al. (2026) showed the good accuracy of MTSTT to estimate fetal weight in the third trimester, and Sakalecha et al. (2023) emphasized the role of MTSTT in late gestational assessment.

While there have been encouraging results reported in previous studies with fetal soft-tissue measurements, there are few studies that evaluate the use of combination of fetal conventional biometry and MTSTT for the prediction of actual fetal weight. In addition, a model that has already been developed might not be applicable in other populations and/or clinical situations. So, studying the association between fetal biometric parameters, MTSTT, and actual birth weight (ABW) might also serve as supporting evidence for the usefulness of adding soft-tissue measurements to routine weight of fetal estimation. This research aims to compare the correlation of antenatal biometry with MTSTT as measured by the US during antenatal period with the ABW of the neonate.

Objectives of the Study

Primary Objective

To compare ABW upon delivery with estimated fetal weight assessed using both Hadlock and Scioscia's formulas.

Secondary Objectives

1. To determine the estimated weight of fetal using Hadlock’s method by evaluating fetal biometry such as BPD, HC, AC, and FL.
2. To measure sonographic MTSTT and calculate the estimated weight of fetal using Scioscia’s formula.
3. To assess how well the estimated weight of fetal calculated by Hadlock’s and Scioscia’s approaches compares with the ABW.
4. To determine whether adding MTSTT enhances fetal weight estimation compared with traditional fetal biometry alone.

2. METHODOLOGY

2.1 Study Design, Setting, and Duration

The aim of this prospective observational study was to assess the correlation of fetal biometry and MTSTT with ABW. The Department of Radiodiagnosis in colloboration with Department of Obstetrics & Gynaecology at Shri Sathya Sai Medical College and Research Institute in Tamil Nadu conducted this study. The 18-month study period began in April 2024 and ended in October 2025.

2.2 Population of Study

Pregnant women in their late third trimester, with gestational ages ranging from 34 to 40 weeks, served as study participants. Pregnant women with a viable fetus, a cephalic position, an appropriate amount of amniotic fluid index according to the gestational age of 34 weeks to 40 weeks were selected for the research. Those women suffering from maternal factors that may influence fetal growth such as hypertension, diabetes mellitus, or any kind of genetic problems were ruled out of the study.

2.3 Calculation of Sample Size

The size of sample was determined using the results of an earlier study that had a prevalence of sonographic measurement accuracy at 89%. The formula used for determining sample size is given by:

$n = 4pq/L^2$

where p = 89%, q = 11%, and L = 7%.

The resulting sample size was 79.92. When the sample size was adjusted for non-response error of 10%, the sample size became 87.82. The final sample size was 88.

2.4 Ultrasound Examination Protocol

Ultrasounds were conducted using a 5.0–7.0 MHz convex transabdominal probe in Voluson P8, Mindray DC-60, and Mindray DC-80 ultrasound equipment. All fetuses underwent ultrasounds only one time. The date of the most recent menstrual cycle was used to calculate the gestational age, which was confirmed by ultrasound results and expressed in weeks. The pregnant woman was positioned in the supine position during the ultrasound test. After exposing her abdomen and applying the ultrasonic gel, the initial ultrasound was done to determine whether the fetus was alive. Foetal parameters like BPD, HC, AC, FL, and MTSTT were later measured.

2.5 Sonographic Parameter's Measurement

The BPD, HC, AC, FL, and MTSTT measurements were done during the ultrasound procedure. The measurement of the MTSTT was performed from the most lateral aspect of the femoral shaft to the most lateral aspect of the skin. The measurement was made using the same frozen image where the FL measurement was made.

Figure 1: Antenatal US image showing measurement of head circumference and biparietal diameter.

Figure 2 : Antenatal US image showing measurement of abdominal circumference**.**

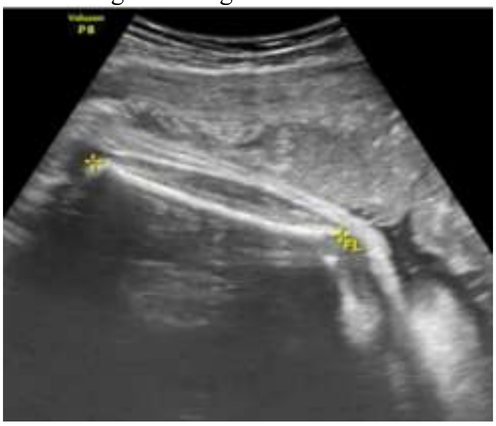

Figure 3 : Antenatal US image showing measurement of femur length.

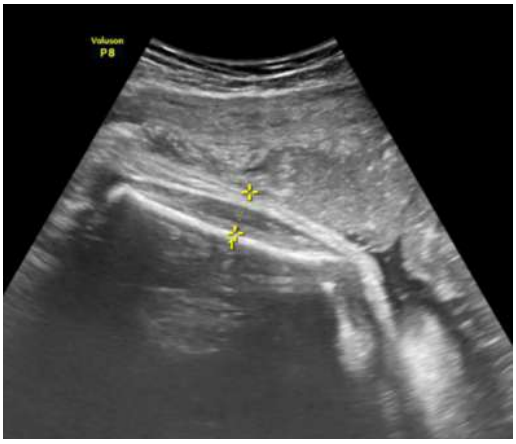

Figure 4 : Antenatal US image showing measurement of Mid-Thigh Soft Tissue Thickness(MTSTT).

2.6 Estimation of Fetal Weight

Estimated fetal weight (EFW) was assessed using two different methods.

Hadlock Formula

EFW using Hadlock's method was automatically calculated by the ultrasound machine based on the measured biometric parameters.

Scioscia's Formula

The EFW using MTSTT was calculated manually using Scioscia's formula:

$EFW = -1687.47 + (54.1 \times FL) + (76.68 \times MTSTT)$

where FL and MTSTT were measured in millimeters. The EFW based on Scioscia's formula was evaluated using SPSS software.

2.7 Measurement of ABW

Shortly after delivery, ABW was noted when the umbilical cord was cut and clamped five centimetres away from the foetal abdomen. Recording was done without any towel or clothes using a calibrated weight scale. The calculated values for the EFW using Hadlock and Scioscia formula were compared to the ABW.

2.8 Statistical Analysis

Data were analyzed using SPSS version 23. Presentation of data was done through use of tables and graphs. Descriptive and relevant statistics were used to find the correlation between the estimated weight of the foetus and the actual weight at birth. The threshold for statistical significance was set at $p<0.05$.

2.9 Ethical Considerations

The Institutional Ethical Committee approved the study before it began. After being made aware of the goals of the study, each participant provided their informed written consent. Patient confidentiality was maintained throughout the investigation.

3. RESULTS

3.1 Maternal Features

Age distribution of the mothers in the study sample is shown in Table 1 below. Majority of women in the study were in the Middle Ages of fertility, with the majority of the women being in their late twenties. Other young and old maternal age groups were relatively small proportions in the study group.

Table 1. Population's maternal age distribution

Age Group (years)	Cases (n)	Percentage (%)
18–22	10	11.1
23–26	22	24.4
27–30	30	33.3
31–34	18	20.0
35–38	10	11.1

As can be observed from Table 1 below, most of the pregnancies took place during the optimum reproductive period. Figure 5 shows the distribution of the study participants' maternal age group.

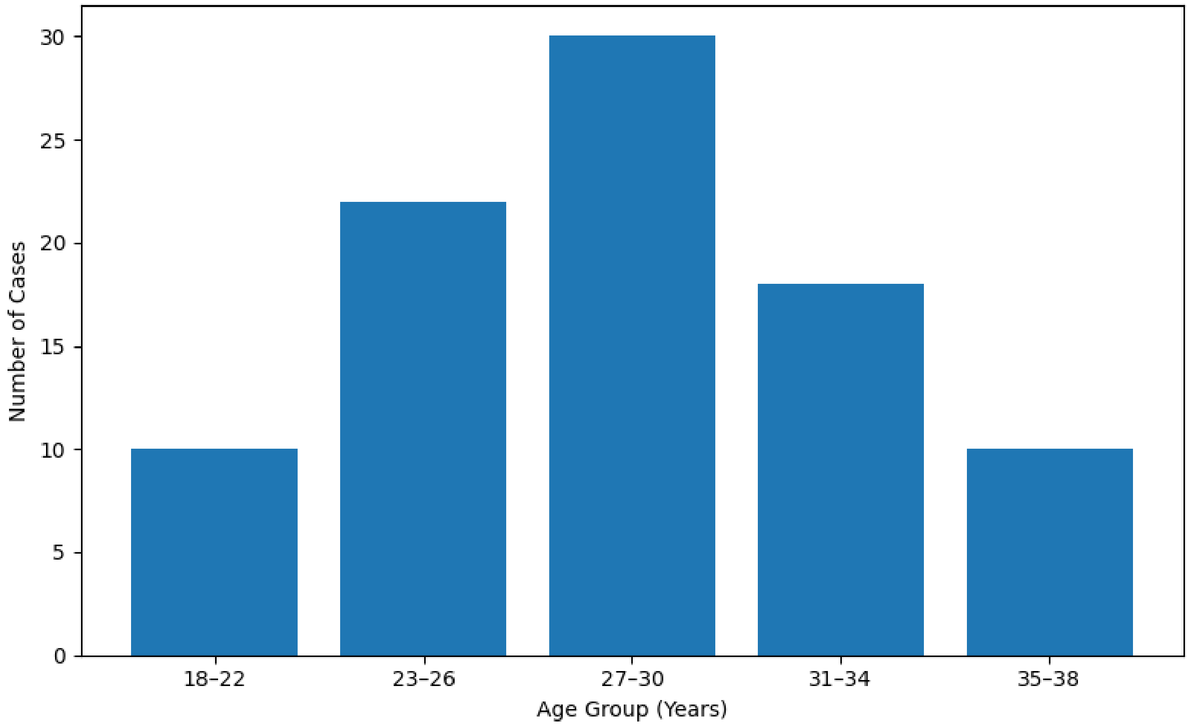

Figure 5. Dispersal of maternal age among the study participants

The age group of 27–30 years had the greatest number of responders, as shown in Fig. 5, followed by the age groups of 23–26 years and 31–34 years. From the distribution, it can be seen that most of the pregnancies in the study took place among individuals in the reproductive period, as compared to those who were younger and older.

3.2 Gestational Age Distribution

Age gestation of the population studied is shown in Table 2. The majority of the pregnancies ended at term, with an accumulation of the subjects during the expected time of delivery. There was only a few pregnancies that exceeded their estimated due dates.

Table 2. Distribution of gestational age in the research population

Gestational Age (weeks)	Cases (n)	Percentage (%)
36–37	14	15.6
38	30	33.3
39	26	28.9
40	14	15.6
41–42	6	6.7

The outcomes from the analysis presented in Table 2 show that the study had many term pregnancies. The age of gestation in the study population has been illustrated in Figure 6.

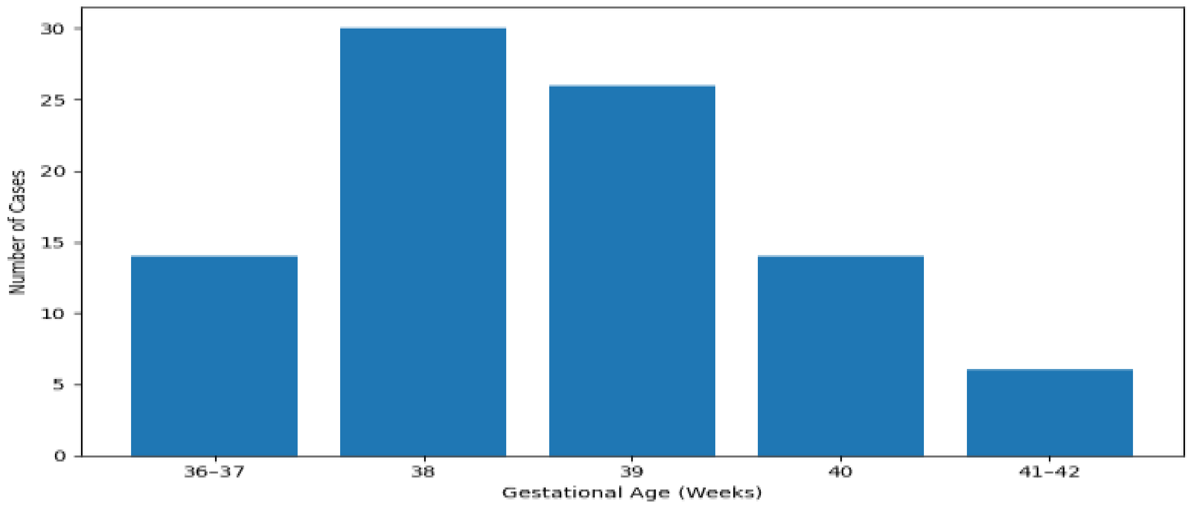

Figure 6. Gestational age distribution in the research population

As shown in Figure 6, the maximum number of deliveries was recorded in weeks 38 and 39 of pregnancy. Deliveries in 36 to 37 weeks and in 40 weeks were less common, and the fewest deliveries were those that were delivered after 40 weeks.

3.3 Sonographic Parameters

3.3.1 BPD

BPD measurements were distributed as shown in Table 3 below. For most fetuses, measurements were within the normal expected range for the late third trimester period, with fewer numbers in the extreme sections of the distribution.

Table 3. Distribution of BPD measurements

BPD Range (mm)	Cases (n)	Percentage (%)
86–88	8	8.9
89–91	19	21.1
92–94	30	33.3
95–97	21	23.3
98–101	12	13.3

From Table 3, most of the BPD values were found to fall in the middle range categories of the distribution. Figure 7 shows the distribution of BPD values.

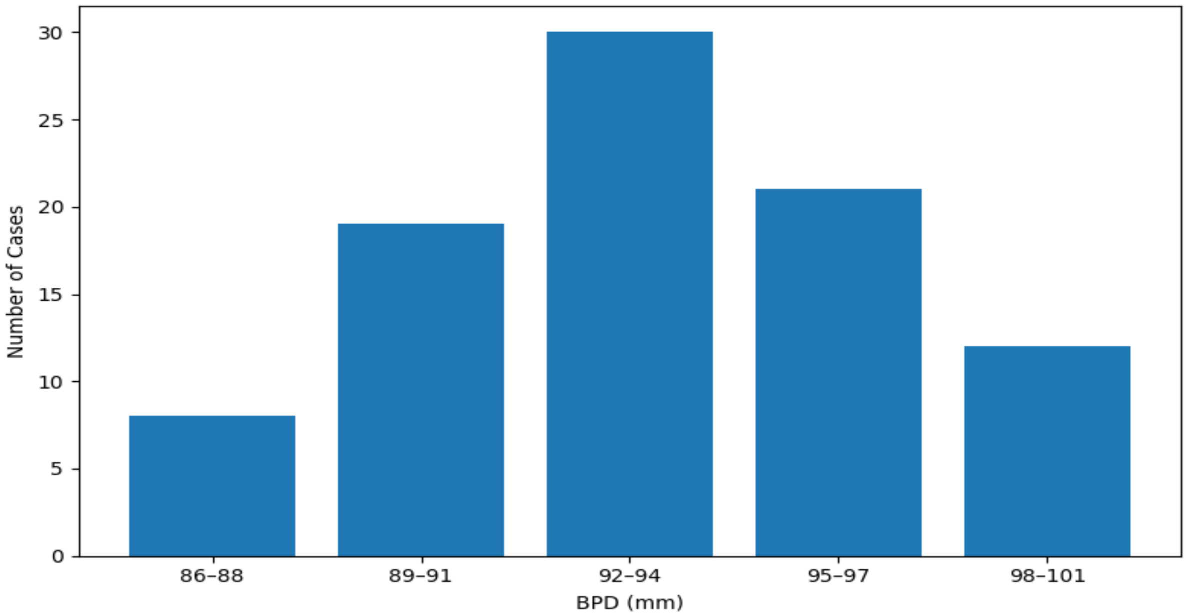

Figure 7. Distribution of BPD measurements among the study population

Figure 7 shows that a higher percentage of foetuses had BPD measurements in the middle range of the distribution. As we move away from the middle towards both extremes of measurements, we find the number of cases decreasing. This implies that BPD values were normal for fetuses.

3.3.2 AC

Table 4 depicts the distribution of measurements for the AC. Most fetuses displayed ACs consistent with normal fetal growth late in gestation.

Table 4. Distribution of AC measurements

AC Range (mm)	Cases (n)	Percentage (%)
270–300	11	12.2
301–320	20	22.2
321–340	29	32.2
341–360	20	22.2
361–390	10	11.1

ACs' values were mostly found to occur in the middle groups as shown in Table 4 below. The distribution of ACs in the study population is depicted in Figure 8 below.

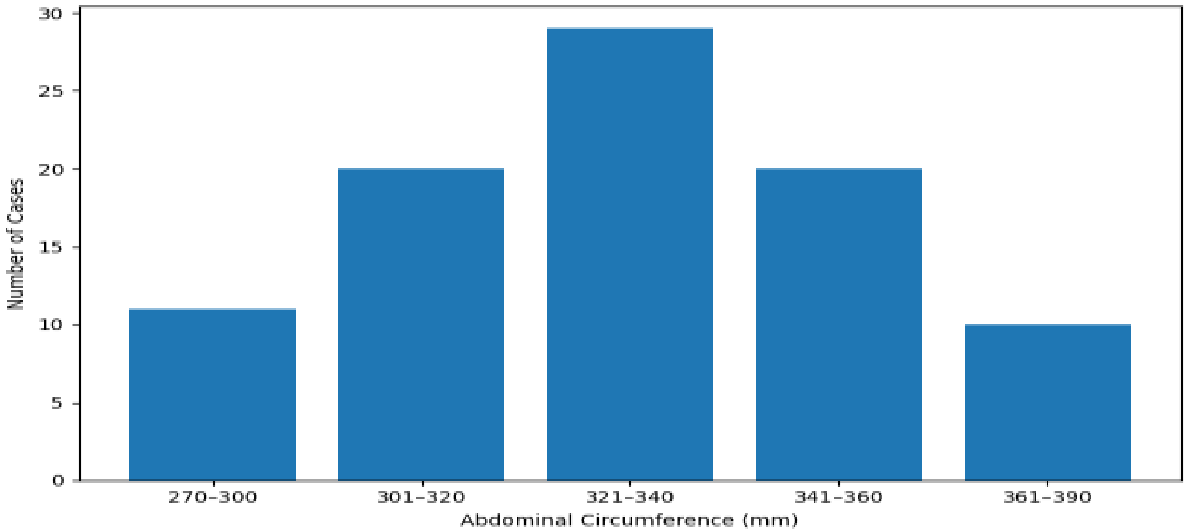

Figure 8. Distribution of AC measurements among the study population

Figure 8, shows that the most of the fetuses had their AC measurements falling within the middle ranges of the distribution. There were fewer cases in both of the extremes, showing that most of the fetuses had their abdominal growth measurements falling within normal fetal growth standards during the third trimester.

3.3.3 FL

The pattern of FLs is shown in Table 5. The FLs fell mostly in the expected range for the gestational ages under study, implying normal development of bones.

Table 5. Distribution of FL measurements

FL Range (mm)	Cases (n)	Percentage (%)
64–67	9	10.0
68–71	18	20.0
72–75	31	34.4
76–79	21	23.3
80–83	11	12.2

As observed from Table 5, most of the FLs were distributed around the medium ranges. The distribution of FL measurements for the study sample is shown in Figure 9 below.

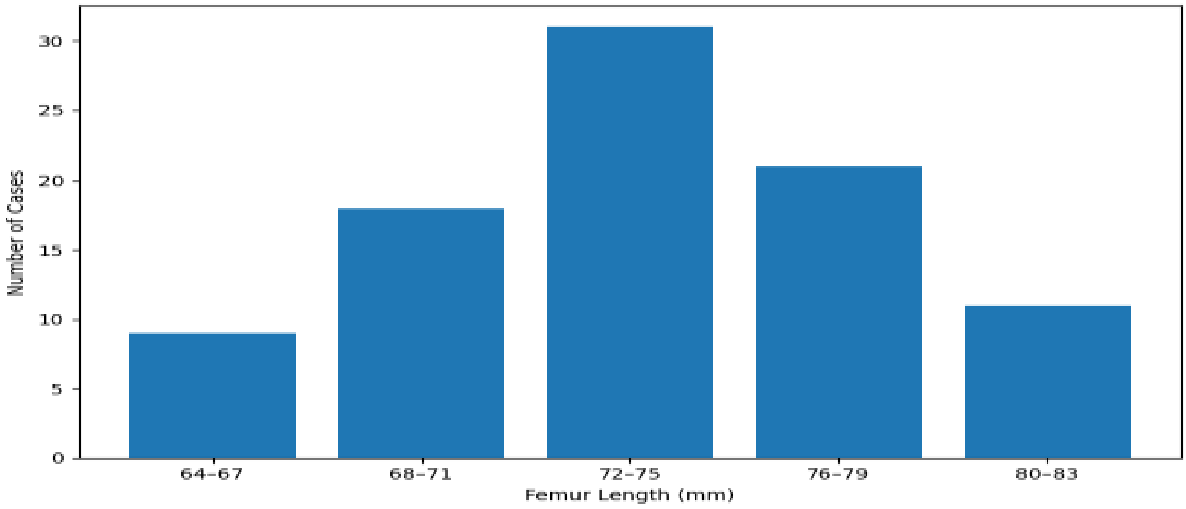

Figure 9. Distribution of FL measurements among the study population

As depicted in figure 9, there were more cases with measurements of the length of the femur within the middle values of the distribution. There was a decline in the number of cases as they got closer to the extreme values on both ends.

3.3.4 MTSTT

The summary of the distribution of MTSTT measurements is provided in Table 6 below. The majority of the fetuses had MTSTT measurements within the middle ranges of the distribution.

Table 6. Distribution of MTSTT measurements

MTSTT Range (mm)	Cases (n)	Percentage (%)
7–10	13	14.4
11–13	24	26.7
14–16	29	32.2
17–19	16	17.8
20–23	8	8.9

The results obtained from Table 6 show that MTSTT readings were mostly distributed in the middle categories of the study subjects. The distribution pattern of MTSTT readings of the study subjects is shown in Figure 10 below.

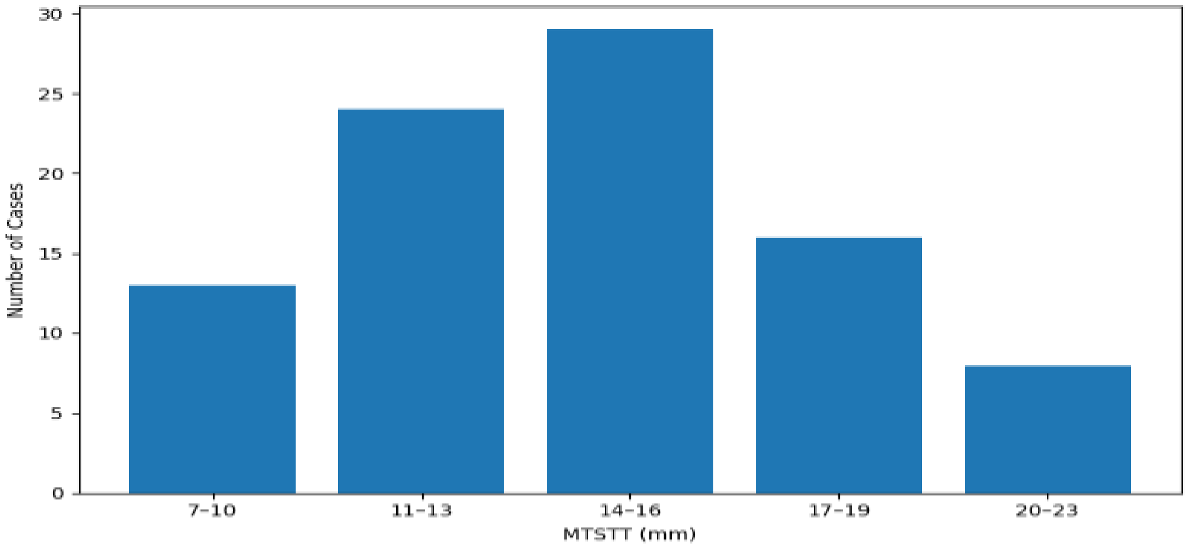

Figure 10. Distribution of MTSTT measurements among the study population

Figure 10 shows that in most cases, the MTSTT values belonged to the central portion of the distribution.

3.4 Birth Weight Distribution

The neonatal distribution of birth weight is indicated in Table 7. The birth weight for most neonates was distributed normally, with very few neonates at both ends of the distribution curve.

Table 7. Distribution of neonatal birth weight

Birth Weight (g)	Cases (n)	Percentage (%)
2200–2600	9	10.0
2601–3000	19	21.1
3001–3400	31	34.4
3401–3800	21	23.3
3801–4400	10	11.1

Table 7 illustrates that most of the neonates' birth weight values were within the middle portions of the distribution, indicative of normal fetal development. The birth weight distribution of the neonates is exemplified in Figure 11.

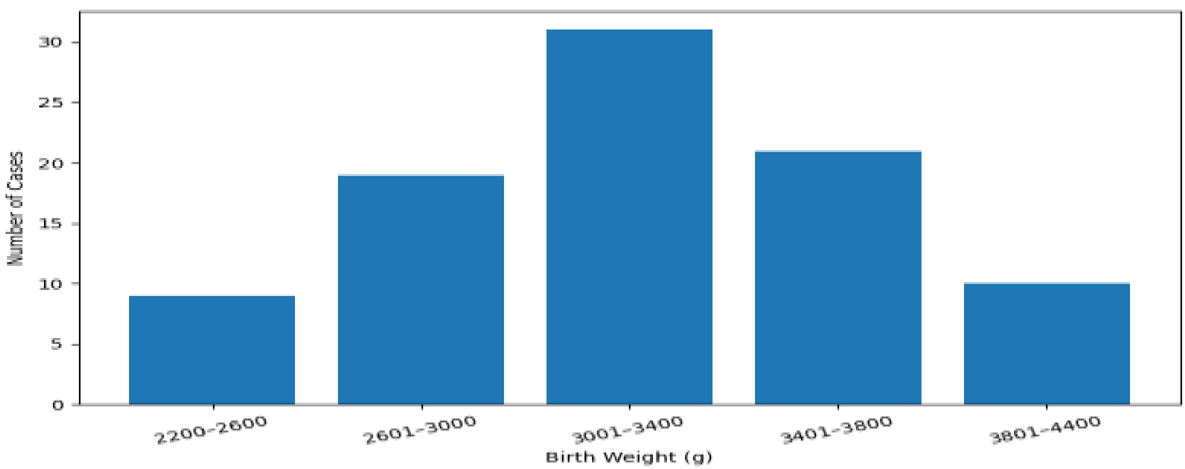

Figure 11. Distribution of neonatal birth weight among the study population

It is clear from Figure 11 below that the bulk of babies had birth weight within the middle ranges of birth weights. The distribution decreased for low birth weight and high birth weight, showing that babies born in this study group had birth weight reflecting normal fetal development.

3.5 Correlation of Ultrasound Parameters with Birth Weight

The relationship between ultrasound parameters and birth weight is displayed in Table 8. All ultrasound parameters tested showed to have a positive and statistically significant association with newborns' birth weight.

Table 8. Correlation of ultrasound parameters with birth weight

Parameter	Correlation Coefficient (r)	p-value
AC	0.67	<0.001
FL	0.65	<0.001
BPD	0.59	<0.001
Soft Tissue Thickness	0.50	<0.001

As depicted in Table 8, the variables which had the most correlation with newborn weight were AC, followed by FL, BPD, and MTSTT. All correlations were significant.

3.6 Multiple Regression Analysis

The multiple regression analysis was conducted in order to assess the overall impact of the sonographic parameters on the birth weight estimation. The obtained equation is provided in Table 9 below.

Table 9. Multiple regression model for prediction of birth weight

Parameter	Regression Coefficient
Constant	2.462
BPD	0.003
AC	0.001
STT	0.007
FL	0.005

Predictive Formula

$\text{Log (BW)} = 2.462 + 0.003 \times \text{BPD} + 0.001 \times \text{AC} + 0.007 \times \text{STT} + 0.005 \times \text{FL}$

$R^2 = 0.76$

A predictive relationship was established by the regression analysis between the ultrasound parameters and birth weight. It should be noted that the variance in the baby's birth weight was explained by the model in a significant way.

4. DISCUSSION

In a prospective observational study of singleton term pregnancies, the association between foetal biometric parameters, MTSTT, and ABW was assessed. The results revealed strong positive association of all the sonographic parameters with birth weight namely BPD, AC, FL, and MTSTT. These variables were most strongly associated with the birth weight (BW), followed by FL, BPD and MTSTT. Moreover, the combined use of conventional biometric and soft-tissue parameters in a regression model showed excellent predictive capacity, thus reinforcing the importance of using both of these parameters for weight of fetal estimation.

The majority of the study population were women within the optimal reproductive age group and majority of pregnancies were delivered at term gestation. Similar results were obtained from the previous studies that assessed fetal weight estimation using ultrasound, which found that term singleton pregnancies were the most common type of pregnancy studied (Hiwale et al., 2019). This relatively homogenous maternal and gestational population was suitable for examining the association of the sonographic measurements and neonatal birth weight.

BPD, AC, and FL showed positive correlations with neonatal birth weight, suggesting their significance as the traditional indicators of fetal growth. Of these parameters the highest association with birth weight was found for AC. This observation is biologically reasonable since abdominal growth is not just skeletal growth but soft tissue growth as well, and is dependent on the nutritional status of the fetus. Zhang et al. (2023) also pointed out that ultrasound-based fetal measurements have also been shown to be useful in predicting neonatal growth outcomes. FL also exhibited a high correlation with BW, in keeping with the fact that skeletal growth accounts for a large portion of fetal growth. Abduljalil et al. (2018) highlighted the need to consider fetal growth assessment by multiple biometric indicators together rather than one at a time.

One of the most important results of this study was the positive strong correlation observed between MTSTT and the birth weight of newborns. MTSTT measures directly the fetal soft tissue development and body composition, unlike conventional skeletal measurements. These results are consistent with previous research. Stanirowski et al. (2021) showed the value of fetal adipose tissue assessment in fetal growth assessments and Sowmya (2018) noted significant correlations between fetal adipose tissue measurements and neonatal anthropometric measures. Similarly, Ikenoue et al. (2017) found an association between measures of fetal body composition derived from ultrasound and newborn adiposity. The observations confirm that MTSTT is a suitable additional parameter for fetal weight estimation.

The present findings are consistent with a number of other studies that support the use of soft-tissue measurements to predict foetal weight. Hamza et al. (2025) found that thigh circumference of the fetus and fractional thigh volume were the best predictor of birth weight. In the same way, Swefy et al. (2024) found that if thigh circumference was added to fetal weight formulas, they would provide more accurate fetal weight estimation. Othman (2026), in a systematic review, concluded that limb-based soft-tissue measurements provide valuable additional information for fetal weight assessment. Erim et al., (2024), also showed that fetal scapula thickness might be a soft-tissue marker that can be used to predict weight of fetal . As a group, these studies corroborate the idea that soft tissue assessment is an adjunct to traditional fetal biometry and aids in the characterization of fetal growth.
The clinical importance of MTSTT is that the assessment of fetal soft-tissue deposition could be done by routine 2-D ultrasonography. Recent ideas of fetal growth increasingly focus on body composition as opposed to just skeletal dimensions. The significance of fetal body composition in growth assessment has been emphasized by Ikenoue et al. (2021), and Cinar and Sezik (2021) found that the limbs-volume measurements showed significant associations with neonatal morphometric outcomes. MTSTT is readily available, and not dependent on specialized equipment, so it could be a useful supplement to the traditional biometric parameters in obstetric routine practice.
The prospective design and the assessment of MTSTT measurement concurrently with traditional foetal biometry within the same patient group are two of the study's strengths. Direct evaluation of the predictive value of sonographic measurements was possible because of the use of ABW as the reference standard. But a few drawbacks must be noted. This study may not be generalizable because it was conducted at a single location with a small sample size. Further, only singleton pregnancies were included, which means that extrapolation to preterm or high-risk pregnancies was not possible. Although standardized protocols exist, ultrasound measurements are operator-dependent, and are subject to variability.
Larger multicenter populations are warranted and other soft-tissue parameters that could further enhance fetal weight prediction should be studied in the future. Anudeep et al. (2025) showed that fetal fat layer and associated sonographic features have the potential to serve as valuable indicators of fetal growth. Moreover, the maternal nutritional and metabolic factors could play a role in fetal growth pattern, as reported by Lawande et al. (2018). These factors should be included in future development of predictive models to expand the accuracy and usefulness of weight of fetal estimation methods in clinical practice.

5. CONCLUSION

The current prospective observational study found a significant correlation between neonatal birth weight and all foetal biometric parameters, including the MTSTT. The sonographic parameters which correlated most closely with birth weight were AC, followed by FL, BPD and MTSTT. The results of these studies reaffirm the continued role of traditional fetal biometry in fetal growth assessment and fetal weight estimation. The strong positive correlation between MTSTT and ABW was an important discovery of this study. Compared with other skeletal measurements, MTSTT will give information about fetal soft-tissue development and body composition, thus providing further information about fetal growth. The regression model developed in this study also showed that the use of MTSTT in addition to the conventional biometric parameters, is an improvement to the prediction of the weight of the newborn. The findings are consistent with those from previous studies that indicated that soft-tissue measurements should be included in ultrasound-based weight of fetal estimation models. MTSTT could be a useful clinical auxiliary parameter, as it is easy to perform, repeatable, and can be used during the simple routine of obstetric ultrasound. In general, the results indicated that the use of fetal biometry with MTSTT may improve the accuracy of fetal weight estimation during pregnancy. The usage of soft tissue measurements in standard fetal monitoring could enhance obstetric management, allow for earlier recognition of abnormal growth patterns and help to improve maternal and neonatal outcomes.

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