



ULTRASONOGRAPHIC ASSESSMENT OF FOETAL LEG BONE LENGTHS FOR ESTIMATION OF GESTATIONAL AGE

Authors name: Suman Inkhiya¹, Ghanshyam Gupta², N K Kardam³

¹Senior Demonstrator, Department of Anatomy, RVRS medical College, Bhilwara

²Former Senior Professor, Department of Anatomy, R N T medical College, Udaipur

³Senior Professor, Department of Radiology, R N T Medical College, Udaipur

corresponding author : Mrs Suman Inkhiya,
Senior Demonstrator, Department of Anatomy, R N T medical College, Udaipur

Email id : inkhiyasuman@gmail.com

Mobile no: 8287039958

ABSTRACT

Background : Accurate estimation of gestational age (GA) is essential for optimal antenatal care, timely obstetric interventions, and assessment of foetal growth. Ultrasonography is the most reliable method for dating pregnancy, with foetal biometry being central to GA estimation. While parameters such as biparietal diameter and femur length are widely used, there is growing interest in evaluating additional foetal leg bones as potential predictors of gestational age.

Aim: To assess the relationship between foetal leg bone lengths measured by ultrasonography and gestational age, and to evaluate their usefulness in estimating gestational age.

Materials and Methods : This cross-sectional observational study included 456 pregnant women between 14 and 39 weeks of gestation. Ultrasonographic measurements of foetal femur, tibia, and fibula lengths were obtained using standardized techniques. Gestational age was calculated based on ultrasonographic dating. Statistical analysis included descriptive statistics, Pearson's correlation, and linear regression analysis to evaluate the relationship between foetal leg bone lengths and gestational age.

Results: The mean gestational age of the study population was 26.36 ± 7.23 weeks. Mean femur, tibial, and fibular lengths were 4.61 ± 1.67 cm, 4.04 ± 1.47 cm, and 3.80 ± 1.38 cm, respectively. Femur length ($r = 0.96$, $p < 0.001$) and tibial length ($r = 0.95$, $p < 0.001$) showed a very strong positive correlation with gestational age, whereas fibular length demonstrated a moderate correlation ($r = 0.59$, $p < 0.001$). Regression analysis confirmed femur and tibial lengths as strong predictors of gestational age.

Conclusion: Foetal femur and tibial lengths show excellent correlation with gestational age and can be reliably used for gestational age estimation. Tibial length, in particular, may serve as a useful adjunct to femur length, especially when conventional parameters are difficult to assess.

Keywords : Gestational age; Ultrasonography; Foetal femur; Tibial length; Foetal biometry

INTRODUCTION

Accurate determination of gestational age is a cornerstone of modern obstetric practice, influencing decisions related to antenatal surveillance, timing of delivery, assessment of foetal growth, and

perinatal outcomes [1]. Errors in gestational age estimation may lead to inappropriate clinical decisions, including misclassification of foetal growth restriction or prematurity [2].

Ultrasonography has emerged as the most reliable and widely accepted modality for estimating gestational age, particularly when performed during early and mid-pregnancy [3]. Conventional ultrasonographic parameters such as crown-rump length in the first trimester and biparietal diameter, head circumference, abdominal circumference, and femur length in the second and third trimesters are routinely used for this purpose [4,5]. Among these, femur length is considered one of the most consistent long-bone parameters due to its linear growth pattern and ease of measurement [6].

However, reliance on a limited number of biometric parameters may be challenging in certain clinical situations, such as abnormal foetal head shape, growth abnormalities, skeletal dysplasias, or suboptimal imaging conditions [7]. This has led to increasing interest in evaluating additional foetal skeletal parameters that may complement existing measurements and improve accuracy in gestational age estimation [8].

Foetal leg bones, including the tibia and fibula, demonstrate predictable growth patterns throughout gestation and are readily visualized on routine obstetric ultrasonography [9]. Several studies have suggested that tibial length correlates closely with gestational age and may perform comparably to femur length, particularly in later gestation [10–12]. Fibular length, though less commonly studied, has also been explored as a supplementary biometric parameter [13].

Despite these observations, there is limited data from the Indian population regarding the utility of foetal tibial and fibular lengths for gestational age estimation. Population-specific reference data are important, as foetal growth patterns may vary with ethnicity and geographical factors [14,15].

The present study was therefore undertaken to evaluate the relationship between foetal leg bone lengths—femur, tibia, and fibula—measured by ultrasonography and gestational age, and to assess their role in estimating gestational age in a tertiary care setting.

MATERIALS AND METHODS

This cross-sectional observational study was conducted in the Department of Radiodiagnosis of a tertiary care teaching hospital after obtaining approval from the Institutional Ethics Committee. Pregnant women attending the antenatal clinic and referred for routine obstetric ultrasonography were consecutively enrolled after obtaining informed consent. A total of **456 pregnant women** with singleton pregnancies between **14 and 39 weeks of gestation** were included in the study. Gestational age was determined based on ultrasonographic dating. Women with uncertain last menstrual period but reliable ultrasonographic dating were also included.

Pregnancies with multiple gestations, foetal congenital anomalies, skeletal dysplasias, intrauterine growth restriction, or maternal systemic illnesses that could affect foetal growth were excluded from the study. This ensured inclusion of uncomplicated pregnancies with normal foetal development for accurate assessment of foetal leg bone growth.

All ultrasonographic examinations were performed using a real-time ultrasound machine equipped with a curvilinear transducer, following standard obstetric scanning protocols. The examinations were carried out with the pregnant woman in the supine position during routine antenatal ultrasound evaluation. Foetal leg bones were visualized in the longitudinal plane, and measurements were obtained from the outer margin of one end of the ossified diaphysis to the outer margin of the opposite end, excluding epiphyses. The foetal femur length, tibial length, and fibular length were measured carefully, ensuring that the bone was positioned horizontally on the screen to avoid obliquity. For each parameter, at least two consistent measurements were obtained and averaged. All measurements were performed by experienced radiologists using standardized anatomical landmarks, in accordance with previously described techniques, to minimize inter-observer variability [16,17].

Statistical analysis

The collected data were entered into a Microsoft Excel spreadsheet and analyzed using standard statistical software. Continuous variables were expressed as mean $\pm$ standard deviation, median, interquartile range, and range. The relationship between foetal leg bone lengths and gestational age

was assessed using Pearson's correlation coefficient. Linear regression analysis was performed to derive equations for estimating gestational age based on femur, tibial, and fibular lengths. A p value of less than 0.05 was considered statistically significant.

RESULTS

A total of **456 pregnant women** in the second and third trimesters were included in the present cross-sectional study. Foetal ultrasonographic measurements of leg bones were analysed in relation to gestational age.

The majority of participants were young women aged 21–30 years and were either primigravida or second gravida. The study population covered a wide gestational age range, enabling assessment of foetal leg bone growth across mid and late gestation.

Table 1: Demographic and Obstetric Profile of Study Participants (n = 456)

Variable	Category	Number (%)
Maternal age (years)	≤20	55 (12.1)
	21–25	202 (44.3)
	26–30	157 (34.4)
	31–35	33 (7.2)
	>35	9 (2.0)
Mean maternal age (years)		25.30 ± 3.93
Gravida	Primigravida	192 (42.1)
	Gravida 2	173 (37.9)
	≥Gravida 3	91 (20.0)
Gestational age by USG (weeks)	Mean ± SD	26.36 ± 7.23
	Range	14.0 – 39.29

All three foetal leg bones demonstrated progressive increase in length with advancing gestational age. Femur length showed the highest mean value, followed by tibial and fibular lengths.

Table 2: Descriptive Statistics of Foetal Leg Bone Measurements (n = 456)

Parameter (cm)	Mean	SD	Median	IQR	Minimum	Maximum
Femur length	4.61	1.67	4.26	3.24–6.36	1.56	7.63
Tibial length	4.04	1.47	3.73	2.86–5.48	1.15	6.90
Fibular length	3.80	1.38	3.50	2.72–5.11	0.96	6.90

A very strong positive correlation was observed between gestational age and both femur length and tibial length. Fibular length showed a moderate but statistically significant correlation with gestational age.

Table 3: Correlation between Foetal Leg Bone Lengths and Gestational Age (n = 456)

Parameter	Pearson's correlation coefficient (r)	P value
Femur length vs GA	0.96	<0.001
Tibial length vs GA	0.95	<0.001

Parameter	Pearson's correlation coefficient (r)	P value
Fibular length vs GA	0.59	<0.001

Linear regression analysis demonstrated that femur length and tibial length are strong predictors of gestational age, with high coefficients of determination. Fibular length showed lower predictive accuracy compared to the other two parameters.

Figure 1: Scatterplot showing correlation between fibular length and gestational age in study subjects

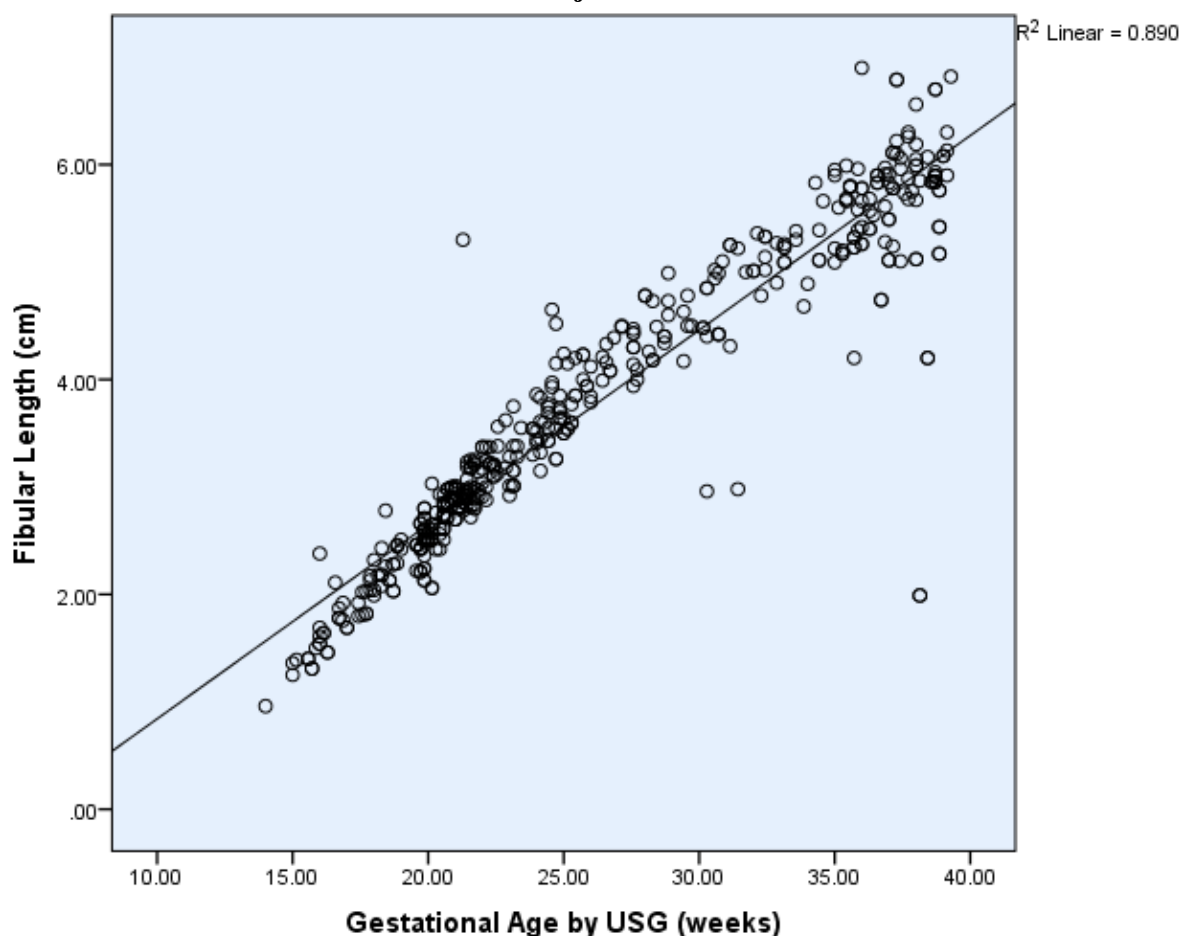


Table 4: Regression Analysis for Prediction of Gestational Age Using Foetal Leg Bones

Parameter	Regression equation
Femur length	$GA = 7.12 + 0.391 \times FL$
Tibial length	$GA = 9.02 + 0.38 \times \text{Tibia length}$
Fibular length	$GA = 8.99 + 0.397 \times \text{Foetal fibular length}$

DISCUSSION

Accurate estimation of gestational age remains a fundamental requirement in obstetric practice, as it directly influences antenatal surveillance, diagnosis of growth abnormalities, and timing of delivery [1–3]. Ultrasonography-based foetal biometry is widely accepted as the most reliable method for gestational age assessment, particularly when last menstrual period is uncertain [4,5]. Among various

biometric parameters, long bone measurements are considered robust due to their predictable linear growth patterns during mid and late gestation [6].

In the present study, foetal femur length demonstrated a very strong positive correlation with gestational age ($r = 0.96$), which is consistent with earlier studies that established femur length as a reliable parameter for gestational age estimation in the second and third trimesters [6,7]. Hadlock et al. [4] and Jeanty et al. [6] reported similar high correlation coefficients, supporting the continued use of femur length as a standard dating parameter. The findings of the present study further reaffirm the validity of femur length in an Indian population across a wide gestational age range.

Tibial length in the present study also showed an excellent correlation with gestational age ($r = 0.95$), closely comparable to femur length. This observation aligns with previous studies that have emphasized the usefulness of tibial length as an alternative or adjunct biometric parameter [10–12]. Rajagopal and Subramaniam [10] reported that tibial length correlated strongly with gestational age and could be used reliably when femur length measurement is difficult. Similarly, Ansari et al. [12] demonstrated that tibial length exhibited a linear growth pattern comparable to femur length, particularly in the later weeks of gestation. The close agreement between femur and tibial correlations in the present study suggests that tibial length may serve as a dependable substitute in situations where femur visualization is suboptimal.

Fibular length, although showing a statistically significant correlation with gestational age in the present study, demonstrated only a moderate strength of association ($r = 0.59$). This finding is in agreement with previous reports indicating that fibular length is less reliable than femur or tibial length for gestational age estimation [13]. Singh et al. [13] noted similar limitations, suggesting that fibular length may be better suited as a supplementary rather than a primary parameter. The relatively lower correlation may be attributed to technical difficulties in consistent visualization of the fibula and greater inter-observer variability.

Regression analysis in the present study further supported the strong predictive value of femur and tibial lengths for gestational age estimation. High coefficients of determination observed for these parameters indicate that a substantial proportion of variability in gestational age can be explained by long bone length measurements alone. These findings are consistent with earlier regression-based models proposed for foetal age estimation using limb bones [4,11]. The inclusion of regression equations enhances the clinical applicability of these measurements, particularly in late gestation when conventional parameters may be affected by biological variation.

An important strength of the present study is the relatively large sample size and inclusion of a broad gestational age range, allowing evaluation of foetal leg bone growth patterns throughout mid and late pregnancy. Additionally, the use of standardized ultrasonographic techniques and measurements performed by experienced radiologists minimized measurement errors and inter-observer variability, as recommended in prior methodological studies [16,17].

Population-specific data are essential for accurate foetal growth assessment, as ethnic and regional variations may influence biometric parameters [14,15]. The present study contributes valuable normative data for foetal leg bone lengths in the Indian population, complementing international standards such as those proposed by the INTERGROWTH-21st Project [5,15]. Incorporation of such data into routine practice may improve gestational age estimation in settings where early pregnancy dating is unavailable.

However, the study has certain limitations. As a cross-sectional study, longitudinal growth patterns of individual fetuses could not be assessed. Additionally, inter-observer variability was not independently evaluated, although standardized techniques were followed. Despite these limitations, the strong correlations observed support the clinical relevance of foetal leg bone measurements.

Overall, the findings of this study highlight that femur and tibial lengths are reliable indicators of gestational age, with tibial length demonstrating comparable accuracy to femur length. Fibular length may be used as an adjunct parameter but should not replace femur or tibial measurements for gestational age estimation.

CONCLUSION

The present study demonstrates that foetal leg bone measurements obtained by ultrasonography show a strong and clinically meaningful relationship with gestational age. Femur length exhibited an excellent correlation with gestational age, reaffirming its role as a reliable parameter for pregnancy dating. Tibial length showed a correlation strength comparable to that of femur length, highlighting its usefulness as an effective adjunct parameter for gestational age estimation, particularly in situations where conventional biometric measurements may be difficult to obtain.

Although fibular length demonstrated a statistically significant association with gestational age, its moderate correlation suggests a supplementary role rather than a primary dating parameter. The regression models derived in this study further support the applicability of femur and tibial lengths for predicting gestational age across a wide gestational age range.

Overall, incorporation of foetal tibial length alongside femur length may enhance the accuracy and flexibility of ultrasonographic gestational age estimation, especially in late gestation and in settings with uncertain menstrual dating. The findings contribute population-specific data that may be useful for improving obstetric ultrasonographic assessment in routine clinical practice.

REFERENCES

1. Hadlock FP, Deter RL, Harrist RB, Park SK. Fetal biparietal diameter: a critical re-evaluation of the relation to menstrual age by means of real-time ultrasound. *J Ultrasound Med.* 1982;1:97–104.
2. Salomon LJ, Alfievic Z, Berghella V, Bilardo C, Hernandez-Andrade E, Johnsen SL, **et al.** Practice guidelines for performance of the routine mid-trimester fetal ultrasound scan. *Ultrasound Obstet Gynecol.* 2011;37(1):116–26.
3. Committee on Obstetric Practice, American College of Obstetricians and Gynecologists. Methods for estimating the due date. *Obstet Gynecol.* 2017;129(5):e150–4.
4. Hadlock FP, Harrist RB, Shah YP, Park SK. Estimation of fetal age using multiple parameters: a prospective evaluation in a racially mixed population. *Am J Obstet Gynecol.* 1984;148(1):7–16.
5. Papageorghiou AT, Ohuma EO, Altman DG, Todros T, Cheikh Ismail L, Lambert A, **et al.** International standards for fetal growth based on serial ultrasound measurements: the INTERGROWTH-21st Project. *Lancet.* 2014;384(9946):869–79.
6. Jeanty P, Romero R, Hobbins JC. Estimation of gestational age from femur length in the second trimester. *J Ultrasound Med.* 1984;3(2):75–8.
7. Scioscia M, Vimercati A, Ceci O, Vicino M, Selvaggi LE. Estimation of gestational age by transvaginal sonographic measurement of fetal long bones. *J Clin Ultrasound.* 2008;36(5):253–8.
8. Exacoustos C, Rosati P. Ultrasound diagnosis of fetal skeletal abnormalities. *Best Pract Res Clin Obstet Gynaecol.* 2008;22(1):117–38.
9. Gindes L, Benoit B, Pretorius DH. Fetal limb biometry: normal values and clinical applications. *Ultrasound Clin.* 2011;6(3):295–307.
10. Rajagopal KV, Subramaniam RK. Tibial length as a predictor of gestational age by ultrasonography. *J Obstet Gynaecol India.* 2010;60(2):145–8.
11. Chitty LS, Altman DG. Charts of fetal size: limb bones. *BJOG.* 2002;109(7):739–44.
12. Ansari SM, Saha M, Paul AK, Haque M, Rahman MM, Ahmed S. Ultrasonographic measurement of fetal tibial length for estimation of gestational age. *Mymensingh Med J.* 2013;22(3):479–84.
13. Singh S, Kumar S, Roy P. Role of fibular length in estimation of gestational age by ultrasonography. *Int J Reprod Contracept Obstet Gynecol.* 2017;6(9):4011–5.
14. Deter RL, Buster JE, Casson PR, Carson SA. Individualized growth assessment: conceptual framework and practical implementation. *Semin Perinatol.* 2004;28(4):273–84.
15. Villar J, Cheikh Ismail L, Vitorica CG, Ohuma EO, Bertino E, Altman DG, **et al.** International standards for newborn weight, length, and head circumference by gestational age and sex. *Lancet.* 2014;384(9946):857–68.
16. Jeanty P, Romero R. *Obstetrical ultrasound: principles and practice.* New York: McGraw-Hill; 2014.

17. Chitty LS, Altman DG. Charts of fetal size: limb bones. *BJOG*. 2002;109(7):739–44.