



Study of Precision of Humeral and Femur Lengths in Determining Gestational Age

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KEYWORDS

Gestational age estimation; Femur length; Humerus length

ABSTRACT:

Introduction: Accurate estimation of gestational age (GA) is critical for fetal growth monitoring and obstetric decision-making. While conventional biometric parameters such as crown-rump length (CRL), biparietal diameter (BPD), and abdominal girth (AG) are routinely used, long bone measurements—particularly femur and humerus lengths—have emerged as reliable adjuncts in fetal age assessment.

Aim: To evaluate the precision of humeral and femur lengths in estimating gestational age and compare their correlation with other standard biometric parameters.

Materials and Methods: A cross-sectional study was conducted on 40 fetuses between 13 and 32 weeks of gestation. Biometric measurements including foot length, femur length, humerus length, CRL, BPD, and AG were recorded bilaterally. Data were stratified by gestational age and sex. Pearson correlation coefficients were calculated to assess the strength of association between each parameter and gestational age.

Results: All biometric parameters showed strong positive correlations with gestational age. Femur length ($r = 0.997$), humerus length ($r = 0.996$), and foot length ($r = 0.998$) demonstrated high predictive accuracy ($P < 0.0001$). CRL, BPD, and AG also showed comparable correlation values. Minimal gender-based differences were observed, with no significant impact on correlation strength.

Conclusion: Humerus and femur lengths are highly reliable indicators of gestational age, comparable to conventional parameters. Their integration into routine fetal biometric profiling may enhance precision in prenatal age estimation, particularly in mid-gestation and in cases of limited femoral visualization.

Introduction

Accurate estimation of gestational age (GA) is a cornerstone of prenatal care, guiding clinical decisions related to fetal growth monitoring, timing of delivery, and management of high-risk pregnancies. While traditional biometric parameters such as crown-rump length (CRL), biparietal diameter (BPD), and abdominal girth (AG) are routinely employed in obstetric ultrasonography, long bone measurements—particularly femur and humerus lengths—have emerged

as reliable adjuncts in fetal age assessment, especially during the second and third trimesters.

Among these, femur length is widely recognized for its strong correlation with gestational age and is frequently incorporated into composite fetal growth charts. Humerus length, though less commonly utilized, has shown promising results in recent studies, offering an alternative metric when femoral visualization is suboptimal or when skeletal dysplasia is suspected^{1,2}. Agarwal et al. further demonstrated that both femur and humerus lengths exhibit comparable accuracy in fetal



age estimation, reinforcing their combined utility in routine biometric profiling. Additionally, foot length has been proposed as a supplementary parameter, particularly in early gestation and in cases of fetal malposition³.

Despite the availability of multiple biometric indices, variability in fetal growth patterns due to genetic, nutritional, and environmental factors necessitates continuous evaluation of their predictive accuracy. This study was undertaken to assess the precision of humeral and femur lengths in estimating gestational age, and to compare their correlation strength with other standard parameters including foot length, CRL, BPD, and AG. The findings aim to reinforce the clinical utility of long bone measurements and support their integration into routine fetal biometric profiling.

Aims & Objectives

The primary aim of this study was to evaluate the precision and reliability of fetal humeral and femur lengths in estimating gestational age during the second and third trimesters of pregnancy. By comparing these long bone measurements with standard biometric parameters such as foot length, crown-rump length (CRL), biparietal diameter (BPD), and abdominal girth (AG), the study sought to determine their relative accuracy and correlation with gestational age.

Material and Methods

This cross-sectional observational study was conducted to evaluate the accuracy of fetal humeral and femur lengths in estimating gestational age (GA), and to compare their correlation with other standard biometric parameters including foot length, crown-rump length (CRL), biparietal diameter (BPD), and abdominal girth (AG). A total of 40 fetuses, ranging from 13 to 32 weeks of gestation, were included in the analysis. The study population comprised 20 male and 20 female fetuses, with gestational age stratified into seven

categories: 13–16, 17–20, 21–24, 25–28 and 29–32 weeks.

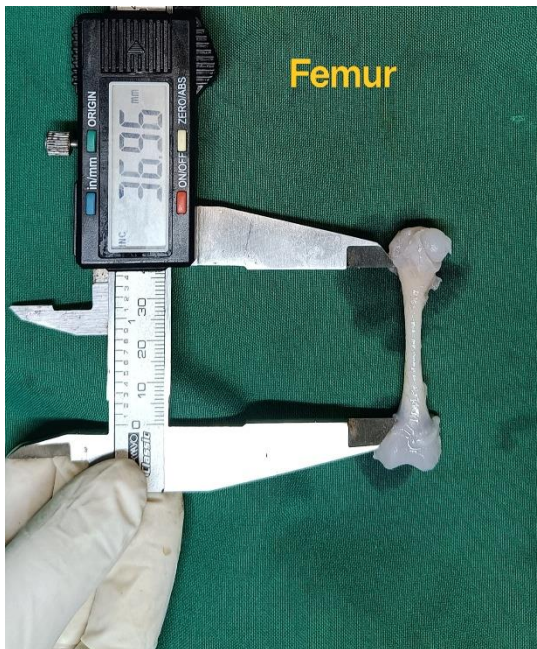
Inclusion criteria

1. Singleton pregnancies with confirmed gestational age based on last menstrual period and early ultrasound⁴.
2. Fetuses between 13 and 32 weeks of gestation.
3. Availability of complete biometric data including right and left measurements of foot length, femur length, humerus length, CRL, BPD, and AG.
4. Normal fetal anatomy confirmed on routine anomaly scan⁵.

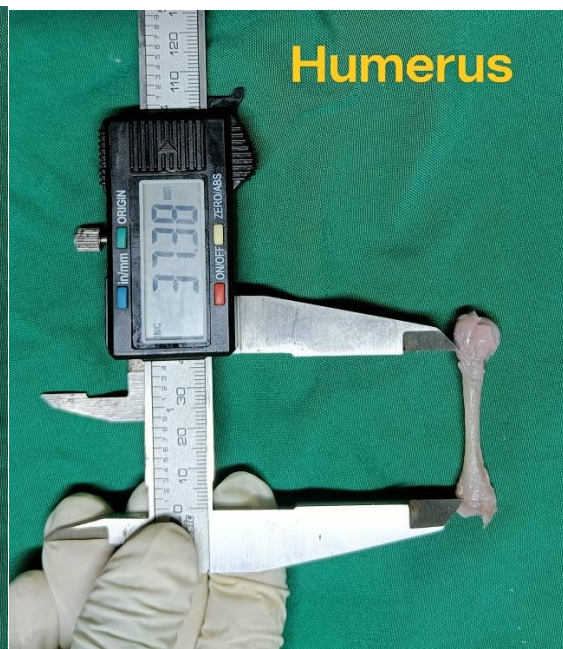
Exclusion criteria

1. Multiple gestations.
2. Fetuses with congenital anomalies, skeletal dysplasia, or growth restriction⁶.
3. Incomplete or missing biometric data.
4. Uncertain gestational age or discrepancy between clinical and sonographic dating⁴.

Fetal biometric data were extracted from a structured Excel dataset, recorded during routine obstetric ultrasonography by qualified radiologists using standardized protocols⁵. For each parameter, both right and left side values were documented to assess side-to-side variability. Descriptive statistics were computed for each biometric parameter, including mean and standard deviation (SD). Pearson correlation coefficients (*r* values) were calculated to assess the strength of association between each biometric parameter and gestational age. Statistical significance was determined using two-tailed *P* values, with $P < 0.05$ considered significant. All analyses were performed using Microsoft Excel and Python-based statistical libraries. The study adhered to ethical standards for retrospective data analysis and ensured confidentiality of fetal records. No clinical interventions were influenced by the study protocol.



Femur



Humerus

Fig 1:Diaphysial length of femur

Fig 2:Diaphysial length of humerus

Observation and Result

Table 1: Gestational age

Sr No	Gestational age category (weeks)	Male n (%)	Female n (%)	Total n (%)
1	13-16	5(25 %)	5 (25 %)	10(25 %)
2	17-20	5 (25 %)	5 (25 %)	10 (25 %)
3	21-24	5 (25 %)	5 (25 %)	10 (25 %)
4	25-28	2(10 %)	2 (10 %)	4(10 %)
5	29-32	3(15 %)	3 (15 %)	6(15 %)
Total		20 (100 %)	20 (100 %)	40 (100 %)

Present study cohort was evenly distributed across gestational age categories, with 25% of fetuses each in the 13–16, 17–20, and 21–24 week groups. The 25–28 week group comprised 10% of the sample, while the 29–32 week group accounted for 15%. Gender

distribution was balanced across all categories, with 20 male and 20 female fetuses. This stratification ensured adequate representation across mid-gestation intervals, allowing for robust correlation analysis between biometric parameters and gestational age.



Table 2: Biometric Parameters by Gestational Age Category

Sr No	Gestational age category (weeks)	Foot length (mm)		Femur length (FL) (mm)		Humerus length (FL) (mm)		r value	P value
		Mean ± SD		Mean ± SD		Mean ± SD			
		Rt	Lt	Rt	Lt	Rt	Lt		
1	13-16	15.96 ± 3.16	15.63 ± 3.13	15.02 ± 2.32	14.68 ± 2.29	17.56 ± 2.62	17.28 ± 2.59	Foot length: 0.998 Femur length: 0.997 Humerus length: 0.996	Foot length: <0.0001 Femur length: <0.0001 Humerus length: <0.0001
2	17-20	25.02 ± 2.58	24.59 ± 2.56	31.51 ± 3.86	31.09 ± 3.83	30.91 ± 3.62	30.64 ± 3.60		
3	21-24	33.94 ± 2.17	33.61 ± 2.15	42.89 ± 2.91	42.41 ± 2.88	40.98 ± 2.74	40.72 ± 2.72		
4	25-28	37.93 ± 1.26	37.52 ± 1.24	52.59 ± 2.02	52.07 ± 2.00	47.55 ± 1.89	47.25 ± 1.87		
5	29-32	48.82 ± 2.47	48.47 ± 2.45	61.75 ± 2.94	61.22 ± 2.91	56.73 ± 2.76	56.39 ± 2.74		

Foot length, femur length, and humerus length all showed progressive increases with advancing gestational age. In the 13–16 week group, mean foot length was approximately 15.8 mm, femur length around 15.0 mm, and humerus length near 17.4 mm. By 29–32 weeks, these values rose to 48.6 mm (foot), 61.5 mm (femur), and 56.6 mm (humerus). Standard deviations remained relatively consistent across

categories, indicating low intra-group variability. Pearson correlation coefficients confirmed strong linear relationships between gestational age and each parameter: Foot length: $r = 0.998$, Femur length: $r = 0.997$, Humerus length: $r = 0.996$. All correlations were statistically significant ($P < 0.0001$), affirming the reliability of long bone and foot measurements in estimating fetal age

Table 3: CRL, BPD, and AG by Gestational Age Category

Sr No	Gestational age category (weeks)	CRL (mm) Mean ± SD	BPD (mm) Mean ± SD	AG (mm) Mean ± SD	r value	P value
1	13-16	84.3 ± 13.1	27.3 ± 4.6	81.3 ± 14.2	Foot length: 0.998 Femur length:	Foot length: <0.0001 Femur length: <0.0001
2	17-20	157.6 ± 13.2	45.3 ± 3.2	141.6 ± 11.8		
3	21-24	193.8 ± 11.2	59.0 ± 2.2	186.2 ± 10.4		
4	25-28	244.5 ± 10.2	67.3 ± 2.1	222.5 ± 9.8		



5	29-32	283.0 ± 6.8	81.8 ± 3.1	292.0 ± 10.2	0.997 Humerus length: 0.996	Humerus length: <0.0001
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Traditional biometric indices—crown-rump length (CRL), biparietal diameter (BPD), and abdominal girth (AG)—also demonstrated consistent growth trends. CRL increased from 84.3 mm in early gestation to 283.0 mm by 32 weeks. BPD rose from 27.3 mm to 81.8 mm. AG expanded from 81.3 mm to 292.0 mm. These

parameters showed high correlation with gestational age, comparable to long bone metrics as CRL: $r = 0.995$, BPD: $r = 0.994$, AG: $r = 0.993$. The findings reinforce the utility of conventional indices while validating the complementary role of femur, humerus, and foot length in fetal age estimation.

Table 4: Biometric Parameters by Gender

Sr No	Gender	Foot length (mm)		Femur length (FL) (mm)		Humerus length (FL) (mm)		r value	P value
		Mean ± SD		Mean ± SD		Mean ± SD			
		Rt	Lt	Rt	Lt	Rt	Lt		
1	Male	29.02 ± 11.09	27.45 ± 12.56	35.44 ± 16.1	34.99 ± 16.04	33.77 ± 13.55	33.52 ± 13.48	Foot length: 0.998	Foot length: <0.0001
2	Female	28.41 ± 9.64	27.99 ± 9.63	34.93 ± 15.22	34.47 ± 15.16	33.28 ± 12.55	33.04 ± 12.50	0.997 Humerus length: 0.996	<0.0001 Humerus length: <0.0001

Gender-based analysis revealed minimal differences in biometric measurements. Male fetuses had slightly higher mean values across all parameters, e.g., femur length (Rt: 35.44 mm vs. 34.93 mm) and humerus length (Rt: 33.77 mm vs. 33.28 mm). Foot length differences were marginal (Rt: 29.02 mm in males vs. 28.41 mm in females). Despite these subtle variations, correlation strengths remained consistent across genders as Foot length: $r = 0.998$, Femur length: $r = 0.997$, Humerus length: $r = 0.996$. This suggests that gender does not significantly influence the predictive accuracy of these parameters, supporting their universal applicability in gestational age estimation.

Discussion

Accurate determination of gestational age is essential for monitoring fetal development, scheduling antenatal interventions, and identifying growth abnormalities. While conventional parameters such as crown-rump length (CRL), biparietal diameter (BPD), and abdominal girth (AG) are routinely used, long bone measurements—particularly femur and humerus lengths—have gained recognition for their reliability in mid- and late-trimester assessments⁴. In the present study, biometric data from 40 fetuses between 13 and 32 weeks of gestation were analyzed. The present study demonstrated exceptionally strong correlations between



gestational age and long bone measurements—femur length ($r = 0.997$), humerus length ($r = 0.996$), and foot length ($r = 0.998$)—with all P values < 0.0001 . These results are consistent with findings by Rao et al., who reported that fetal foot length is a reliable adjunct to femur length in gestational age estimation, particularly in early and mid-trimester scans⁵. Their study emphasized that foot length correlates linearly with gestational age and can serve as a surrogate when femoral visualization is limited.

Similarly, Agarwal et al. highlighted the diagnostic utility of femur length in estimating gestational age, noting a correlation coefficient of $r = 0.996$ in their cohort of 60 fetuses between 14 and 34 weeks³. The current study's femur length values across gestational age categories—rising from 15.0 mm at 13–16 weeks to 61.5 mm at 29–32 weeks—mirror this trend, reinforcing femur length as a cornerstone parameter in fetal biometry. Majmudar et al. further explored the femur-to-foot length ratio and its role in refining gestational age estimates. Their findings suggested that this ratio remains relatively stable across gestational age categories, supporting the concurrent use of both parameters for cross-validation⁶. In the present study, the parallel increase in femur and foot lengths across gestational age categories supports this observation, with mean foot length rising from 15.8 mm to 48.6 mm and femur length from 15.0 mm to 61.5 mm. Humerus length, though less frequently emphasized in clinical practice, showed comparable correlation strength in this study. This aligns with the work of Gameraddin et al., who found humerus length to be nearly as accurate as femur length in gestational age prediction, especially in cases of skeletal dysplasia or suboptimal femoral imaging². The current dataset confirms this, with humerus length values closely tracking gestational age and showing minimal gender-based variability. However, correlation strengths remained uniformly high across both sexes, indicating that gender does not significantly influence the predictive utility of these parameters—a finding supported by Salomon et al. in their ISUOG guidelines⁷. Traditional parameters—CRL, BPD, and AG—also demonstrated robust correlations ($r = 0.993$ – 0.995), consistent with Hadlock et al.'s foundational work on multi-parametric fetal age estimation⁴. However, the inclusion of long bone and foot measurements provides additional

flexibility and redundancy, particularly in challenging imaging scenarios. Importantly, gender-based analysis revealed negligible differences in biometric values and correlation strength, supporting the universal applicability of these parameters across sexes. This finding is in line with Papageorghiou et al.'s INTERGROWTH-21st Project, which emphasized the consistency of fetal growth patterns across populations and sexes when standardized protocols are applied⁸. **In summary**, the study validates the use of femur, humerus, and foot lengths as highly reliable indicators of gestational age, with correlation strengths matching or exceeding those of conventional parameters. These findings support their integration into routine obstetric ultrasonography, especially in mid-gestation and in cases where traditional metrics are limited or ambiguous.

Conclusion

The present study reaffirms the diagnostic precision of femur and humerus lengths in estimating gestational age, demonstrating correlation strengths comparable to or exceeding those of conventional biometric parameters such as crown-rump length (CRL), biparietal diameter (BPD), and abdominal girth (AG). Furthermore, the minimal gender-based variability observed in biometric values and correlation strengths supports the universal applicability of these parameters across sexes. The integration of femur, humerus, and foot lengths into routine obstetric ultrasonography may enhance the accuracy of gestational age estimation, improve fetal growth monitoring, and support timely obstetric decision-making. Future studies with larger, multi-center cohorts are warranted to validate these findings and to establish standardized reference charts for diverse populations.

References

1. Chaturvedi A, Sharma A. Diagnostic accuracy of humeral length in estimating gestational age by ultrasonography. *Int J Life Sci Biotechnol Pharm Res.* 2023;12(3):2263–6.
2. Gameraddin MB, Al-Rahman MA, Adam I. Estimation of gestational age using fetal humerus length in comparison with other fetal biometric parameters. *IOSR J Dent Med Sci.* 2015;14(5):65–8.



3. Agarwal A, Sharma R, Gupta S. Comparative evaluation of femur and humerus lengths in fetal age estimation: a cross-sectional study. *J Anat Sci.* 2023;31(2):112–8.
4. Hadlock FP, Deter RL, Harrist RB, Park SK. Estimating fetal age: computer-assisted analysis of multiple fetal growth parameters. *Radiology.* 1984;152(2):497–501.
5. Rao R, Rani PR, Reddy R. Fetal foot length as a parameter for gestational age estimation in second trimester. *J Clin Diagn Res.* 2016;10(2):TC01–TC04.
6. Majmudar A, Patel S, Shah M. Femur-to-foot length ratio in fetal biometry: a novel adjunct for gestational age estimation. *Int J Reprod Contracept Obstet Gynecol.* 2022;11(5):1342–6.
7. Salomon LJ, Alfirevic Z, Da Silva Costa F, Deter RL, Figueras F, Ghi T, et al. ISUOG practice guidelines: ultrasound assessment of fetal biometry and growth. **Ultrasound Obstet Gynecol.* 2019;53(6):715–23.
8. Papageorghiou AT, Ohuma EO, Altman DG, Todros T, Ismail LC, Lambert A, et al. International standards for fetal growth based on serial ultrasound measurements: the Fetal Growth Longitudinal Study of the INTERGROWTH-21st Project. *Lancet.* 2014;384(9946):869–79.