



Estimation of Gestational Age from Human Fetal Diaphyseal Length of Femur

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ABSTRACT

Introduction: Length of femur is the good marker of late gestational age. Femur length denotes exact gestational age and helps in classification of fetus as pre-term, term or post-term. Also, it is an important parameter in medicolegal cases like decomposed fetuses, infanticide and mutilated parts of fetus. This study was mainly conducted to estimate the gestational age from human fetal diaphyseal length of femur.

Material and Methods: Study was conducted on 35 human aborted fetuses obtained from OBGY department of MGM Medical college, Aurangabad and 70 femurs of right and left side were dissected out in Anatomy department of same institute for the fetal femur morphometry and its correlation with gestational age. Fetuses were divided into 4 groups as A, B, C, D according to their gestational age and diaphyseal length i.e., measurement from greater trochanter to lateral condyle (L1) was measured.

Results: In each group following parameter was analyzed by descriptive statistics. The Mean +SD, minimum and maximum values for diaphyseal length of femur (L1) was calculated in each group. L1 of right femur increases gradually from 38.96 mm in group A to 74.294 mm in 32 in group D. Similarly for left femur, the diaphyseal length increase gradually from 38.971 mm in group A to 76.594 mm in group D. The mean diaphyseal length L1 of both right and left side is 38.95 in group A and 75.44 in group D, shows linear correlation with gestational age. It was found that femur length gives a positive correlation with gestational age.

Conclusion: Diaphyseal length of fetal femur, is one of the most important parameter for the estimation of gestational age in 2nd and 3rd trimester.

Key Words: Fetal femur length (L1), Gestational age, Crown rump length, Greater trochanter, Lateral condyle, Univariate statistical equations, Femur growth, Medicolegal importance, Ossification, Diaphyseal length

INTRODUCTION

Knowledge of gestational age is important to know the events of intrauterine development and to predict the various outcomes of the fetus like fetal viability, expected date of delivery, and for classification of fetus as preterm, term or post term. It is also an essential tool in obstetrics to plan appropriate prenatal and perinatal care in malformed fetuses and counseling women who are at high risk of recurrent abortions.¹ Prior to ultrasonography, calculation of gestational age was based on the calculation from the last menstrual period (LMP) but it is often unreliable as it is based on the woman's memory.

Campbell et al. (1985), showed in his study of more than 4000 pregnant women, that 45 % of women were not sure about their last menstrual period because of irregular cycles,

use of oral contraceptives pills, bleeding in early pregnancy, and poor recall of menstrual history.²

During 2nd and 3rd trimester, fetus can be studied from the long bones that grow parallel with that of fetus. These bones are femur, tibia, humerus, radius, clavicle etc. Femur is one of the most important morphometric indices for growth and development of fetus in 2nd and 3rd trimester because, Femur is the longest bone, it is easily measurable, and can be easily studied and will be helpful to correlate with other studies. The findings gained from femur will be helpful to provide standard growth charts for estimation of gestational age.³

Though ultrasonography is useful but there are some limitations with its use. Measurement by ultrasonography may vary from person to person, the result obtained may be unreliable due to frequent change of fetal position, due to fe-

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tal movement, the quality of equipment used, experience of sonologist and comparative measurement charts. Moreover, for the estimation of gestational age by USG, acoustic shadowing interferes with the accurate measurement of the full thickness of ossified diaphysis. Also in Medicolegal cases, like decomposed fetuses, infanticides or mutilated parts of fetus, estimation of fetal viability is of most importance, but by ultrasonography it is not possible and shows its limitation in forensic cases. Hence, there is no doubt that manual measurements will give the most precise data when compared to ultrasonography, thus enhancing the scope of study on fetal anatomy

This study is carried out to estimate the relationship of femur growth parameters with gestational age during second and third trimester of Indian population, by actual dissection method which will help to prepare the charts of fetal parameters with respective gestational age.

MATERIAL AND METHODS

Present study was conducted in Anatomy department, MGM medical college Aurangabad on 35 aborted fetuses of 2nd and 3rd trimester obtained from OBGY department. After getting approval from ethical committee fetuses were selected as per inclusion and exclusion criteria and was numbered as F1, F2, F3 etc.

Inclusion Criteria:

1. Aborted fetus of second and third trimester i.e. 13 -32 weeks of gestation irrespective of sex.
2. Singleton pregnancy.

Exclusion Criteria:

1. Gross fetal anomaly.
2. Congenital fetal anomaly.
3. Skeletal deformity
4. Twin pregnancy
5. Maternal history of diabetes, hypertension or any endocrinal disorder.

Each fetus where weighted, CRL was calculated for gestational age and then dissection of both side femur was done. Following parameters, for right and left femur were calculated separately and noted in excel sheet.

1. **Fetal weight (FW in grams Photograph 1):** After washing and drying each fetus along with 5 cm umbilical cord was measured on scientific weighing machine and reading was recorded in excel sheet.
2. **Crown rump length (CRL in mm Photograph 2):** was measured from the outer edge of vertex to the bottom of the fetal rump with the help of sliding vernier caliper.

DISSECTION OF Femur- (Photograph 5 and 6)

Each fetus was given an identification number as F1, F2, F3 etc. 10% formalin solution with the help of syringe was injected into cavities of fetus, i.e., in the cranial cavity, abdominal cavity, thoracic cavity, and thigh region and each fetus was immersed in 10% formalin solution for 2-3 days for proper fixation. The femur was dissected out by making two incisions, one horizontal incision was taken at the level of iliac crest and vertical incision along the lateral aspect of thigh up-to knee joint. Skin, Deep fascia and muscles of thigh were exposed.

The muscles are divided longitudinally to expose the hip joint. The proximal end of femur was grasped and the muscles were dissected away from the bone to prevent bone damage as the bone can easily break. **(Photograph 5)**

The hip joint capsule was incised and the femoral head was mobilized by cutting the ligament of the head of femur. The knee joint capsule was opened and knee joint ligaments were incised. Thus, finally the femur was removed and fixed in a jar of formalin. Same procedure was performed for the left femur also. Both femur of one fetus were given labels and kept together in 10% formalin jar. Both femurs were included in the study.

Measurements after dissection

After taking dissected femur in a tray, unwanted associated muscles and surrounding connective tissue and ligaments were removed.

Following parameters, for right and left femur were calculated separately and noted in excel sheet.

1. Weight of femur (FeW in grams photograph 3) Weight of right and left femur was measured in grams with the help of digital scientific weighing machine.
2. Diaphysial length of femur (L1 in mm photograph 4) Maximum distance between Greater Trochanter to Lateral condyle.

Final reading for all parameters was obtained by taking an average of 3 readings for getting maximum accuracy.

Fetuses were divided into 4 groups as A, B, C, D according to their gestational age as given in following table no. 1

Table 1: Fetuses divided into 4 groups according to their

Group	Gestational age name [weeks]	Number of fetuses
A	13-16	10
B	17-20	15
C	21-24	5
D	25-32	5

RESULTS

The mean, standard deviation, minimum and maximum values of each fetal femur measurements was calculated in each group. Femur length gives a positive correlation with gestational age. (Table 4)

Right Femur Length [L1 in mm]

Table 2 shows gradual increase in diaphyseal length of femur L1 with GA

In mean Rt. femur diaphyseal length L1 increases from 38.936 to 74.294mm in span of 13 to 32 weeks of gestation.

Graph 1 shows linear correlation between Rt. femur length L1 and gestational age.

Linear equation is $y = 2.7047x - 0.1789$ with $R^2 = 0.8834$

Polynomial equation is $y = 0.0009x^4 - 0.0648x^3 + 1.5822x^2 - 11.401x + 28.02$ with R^2 value of 0.909

Both R^2 values are suggestive of positive correlation between Femur length L1 Rt. and gestational age.

Left Femur Length (L1 in mm)

Table 3 shows gradual increase in left diaphyseal length of femur with gestational age.

Mean left diaphyseal length of femur increases from 38.971 mm to 76.754 mm in span of 8 to 36 weeks of gestation.

Graph 2 shows linear correlation between left diaphyseal length of femur and gestational age.

Linear equation is $y = 2.8153x - 1.6191$ with R^2 value = 0.8893

Polynomial equation is $y = 0.0002x^4 - 0.0049x^3 - 0.2583x^2 + 13.259x - 93.582$ with R^2 value = 0.913

Both R^2 values are suggestive of positive correlation between left diaphyseal length of femur of and gestational age.

DISCUSSION

The aim of the present study was to estimate the gestational age with diaphyseal length of femur and the accuracy of diaphyseal length of femur to correlate with gestational age by means of direct anatomical measurement.

35 aborted fetuses of 13 to 32 weeks of gestation were studied in the group of 4 as A, B, C, D according to their gestational age.

Fetal femur parameter where subjected to statistical analysis, to correlate fetal femur growth with GA, by univariate statistical equations.

It was found that, there is linear correlation between the gestational age and parameters like diaphyseal length of femur, in 2nd and 3rd trimester of pregnancy. Linear correlation is also seen between the femur length and gestational age.

The present study, also showed high linear correlations between femoral parameter with increase in GA. This shows the importance of these parameter in advanced pregnancy. The significant correlation of GA with FL1 rt. ($R=0.940$) and Lt. ($R=0.943$), indicating that fetal femur can be used as one of the important parameters to estimate gestational age in 2nd and 3rd trimester.

Present study shows linear correlation of diaphyseal length of femur with gestational age. L1 of right femur increases gradually from 38.96 mm in group A to 74.294 mm in 32 in group D. Similarly for left femur, the diaphyseal length increase gradually from 38.971 mm in group A to 76.594 mm in group D. The mean diaphyseal length L1 of both right and left side is 38.95 in group A and 75.44 in group D, shows linear correlation with gestational age.

It also correlates with the findings of **Vidhu Dhawan et al. (2014)**, who concluded that there is gradual increase in diaphyseal length of femur with gestational age.⁴

The mean of other groups compared to that of **Vidhu Dhawan et al. (2014)** showed a deviation due to difference in amount of data, sample size, grouping difference, genetic, nutrition, environmental and population factor.⁴

Khan Z and Faruqi Na (2006) observed that growth rate of femur was relatively higher i.e. more than 12 mm per month between 4th to 6th months, which were similar to the present findings.⁵

Mukta Mital, Prasant Gupta, Vineet Nanda (2014) states, that, in cases of fetal hydrocephalus, short limbs or anencephaly, fetal femur to foot ratio is useful in detection of skeletal dysplasia.⁶

Chaithra Rao B R (2017) observed that the diaphyseal length of femur gradually increases from 15 weeks to 40 weeks of gestation and found a strong linear and direct correlation between the diaphyseal length of femur and the gestational age. Similar result were found in present study.⁷

Taner Ziyen, Khalil Awadh Mursid (2003) studied femur parameters in Turkish population in 30 aborted fetuses and positive correlation was observed between GA and femur length L1 in their study as observed in present study. and concluded that both, the CRL and femur length are accurate for determining gestational age.³

The study performed by **Carneiro et al. (2013)**, by radiograph also showed positive significant correlation ($R=0.969$; $p=0.000$) between GA and femur length L1, which is in conformity with present study ($R=0.943$; $p=0.000$)

and concluded that the GA can be accurately determined by regression equations derived from the diaphyseal length of the long bones. In the present study, we observed diaphyseal length of femur shows linear correlation and can be used to estimate gestational age.⁸

Comparable results were found in the studies done by ultrasonographic method, though the mean values by direct method are high. The reason is methodological differences. As the ultrasonic examination were carried on the ossified femur diaphysis and not on the entire length of bone.

Vidhu Dhawan et al. (2014) studied 45 aborted fetuses in Indian population. He found a significant coefficient correlation for L1 ($R=0.837$) and for L2 ($R=0.866$). The values are slightly less, as compared to present study. This difference could be because of sex difference of fetuses, grouping difference and sample size in their study.⁴ (Table 6)

Present study derived following polynomial univariate Equations which gives better R^2 values compared to linear equations –

- **Right Diaphyseal length of femur (L1)**
 $y = 0.0009x^4 - 0.0648x^3 + 1.5822x^2 - 11.401x + 28.02$
 $R^2 = 0.909$
- **Left Diaphyseal length of femur (L1)**
 $a = 0.0002x^4 - 0.0049x^3 - 0.2583x^2 + 13.259x - 93.582$,
 $R^2 = 0.913$

Univariate Analysis

Estimation of GA from femur parameters

- **Right diaphyseal length of femur (L1)**
 $a = 0.0023x^2 + 0.0694x + 9.1046$
 $R^2 = 0.900$
- **Left diaphyseal length of femur (L1)**
 $a = 0.0027x^2 + 0.0078x + 10.784$
 $R^2 = 0.9159$

CONCLUSION

The conclusions of present study are:

- The average weight of the fetus proportionally increases with gestational age. Present study found that increase in fetal weight in Indian fetuses is linear, it can be used as good indicator for estimation of gestational age.
- Parameter like CRL show linear correlation with gestational age and can be used to estimate gestational age.
- Dimensions of fetal femur diaphyseal length L1 of both sides established strong and linear correlation with gestational age. (Table 6)
- Right and left diaphyseal length L1 increase with increase in gestational age.

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Ethical clearance number: MGM-ECRHS/2019/86

Source of funding – None

Conflict of interest – None

Author's Contribution – 1st Author: Sana Khan – Dissection of fetus and collection of data.

2nd Author: Vaishali Mandhana - Helped in Preparing Manuscript.

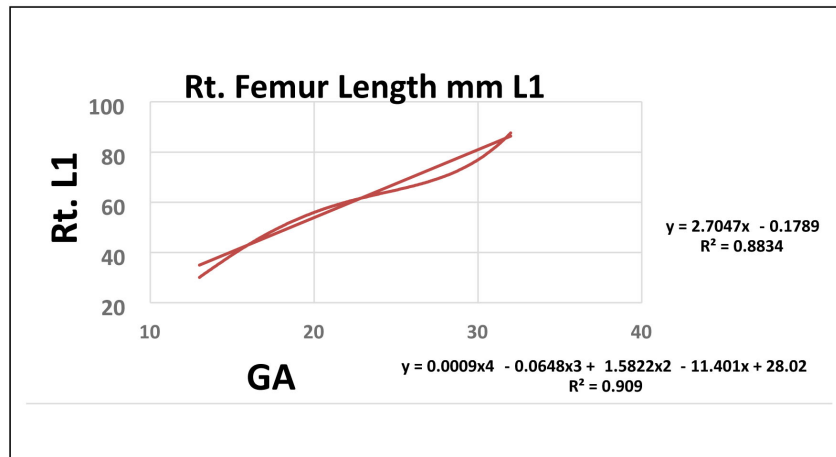
3rd Author: Gautam Shroff – Helped in statistical analysis.

REFERENCES

1. Carol B, Peter M. Callens ultrasonography in obstetrics and gynecology. sixth edition. Philadelphia: Elsevier. 2017; p.118-131.
2. Campbell S, Wars of SL, Little D, Cooper DJ. Routine ultrasound screening for the prediction of gestational age. *Obstet Gynecol.* 1985 May;65(5):613-20.
3. Ziyen T, Murshid KA. An assessment of femur growth parameters in human fetuses and their relationship to gestational age. *Turk J Med Sci.* 2003; 33: 27-32.
4. Vidhu D, Kanchan K, Mahesh S, Balbir S, Alka S. Morphometry of fetal femora as an indication of gestational age: *Eur. J. Anat.* 2014;18 (2): 85-92.
5. Khan Z, Faruqi NA. Determination of gestational age of human fetuses from diaphyseal lengths of long bones-A Radiological study. *J. Anat. Soc. India.* 2006; 55[1]:67-71.
6. Mukta M, Prashant G, Vineet N. "Fetal gestational age estimation by fetal foot length measurement and femur to foot length ratio in Indian population-A prospective study." *JEMDS.* 2014 March; 3(10):2620-2625.
7. Chaithra Rao BR, Sunkeswari S, Kalghatgi RN. The study of relation between gestational age of human fetuses and diaphyseal length of femur using ultrasonography. *Int J Anat Res* 2017, 5(1):3342-49.
8. Carneiro C, Curate F, Borralho P, Cunha E. Radiographic fetal osteometry: Approach on age estimation for the Portuguese population. *Forensic Sci Int.* 2013 Sep 10; 231(1-3): 397. e1-5
9. Beazly JM, Underhill RA. Fallacy of the fundal height. *Br Med J.* 1970; 4: 404-6.
10. Andrzej MB, Małgorzata K, Joanna M, Bartłomiej MK, Jerzy SG. Is manual foot length measurement of comparable value to ultrasound femur and humerus measurement in anatomical studies for the assessment of foetal age? *Folia Morphol.* 2004 May; 63(2):203-7.

Table 2: Relation of Rt. diaphyseal length of femur (L1) with gestational age

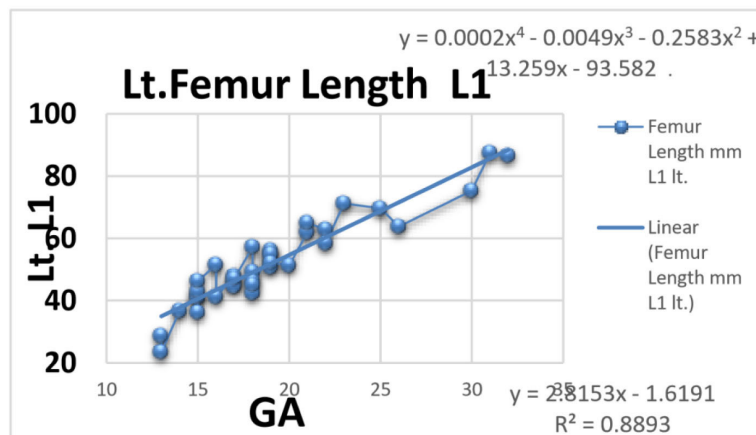
Group	Min.	Max.	Mean	SD
A	25.39	51.07	38.936	7.66711
B	41.5	55.81	49.126	4.552977
C	58.03	70.64	63.258	4.718662
D	61.87	86.81	74.294	11.94616



Graph 1: Relation of Rt. Diaphysial length of femur L1 with GA.

Table 4: Mean and SD of right and left femur parameters

Group		L1	N
A	Mean	38.9535	20
	SD	11.74	
B	Mean	49.427	30
	SD	4.5965	
C	Mean	63.571	10
	SD	4.7275	
D	Mean	75.444	10
	SD	11.167	



Graph 2: Relation of left diaphyseal length of femur with gestational age.

Table 5: Pearson Correlation between GA and L1 Rt. and Lt.

	GA in weeks		L1 rt.	L1 Lt.
Pearson	G A weeks	1.000	.940	.943
Correlation	Femur Length mm L1 rt.	.940	1.000	.995
	Femur Length mm L1 Lt.	.943	.995	1.000
Sig. (1-tailed)	G A weeks	.00	.000	.000
	Femur Length mm L1 rt.	.000	.000	.000
	Femur Length mm L1 Lt.	.000	.000	.0
N	G A weeks	35	35	35
	Femur Length mm L1 rt.	35	35	35
	Femur Length mm L1 Lt.	35	35	35

Table 6: Comparison of diaphyseal length of femur L1

		A	B	C	D
L1	Vidhu Dhawan	22	33	49	69
	Present study	38.95	49.427	63.571	75.44



Photograph 1: Fetus weight.



Photograph 3: Femur weight.



Photograph 2: CRL.



Photograph 4: Diaphysial length L1.



Photograph 5: Incision for femur.



Photograph 6: Femur in situ.

ETHICAL COMMITTEE APPROVAL LETTER



Ethics Committee for Research on Human Subjects

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MGM-ECRHS/2019/58 Date: 10th Oct., 2019

MGM - ECRHS APPROVAL LETTER

To,
The PI: Khan Sana
Department of Anatomy (M.Sc.)
MGM Medical College, Aurangabad

Dear Dr,

The meeting of Ethics Committee for Research on Human Subjects (ECRHS) was held on 10th Oct., 2019 at 10 AM. in the Boardroom with Dr. Manvendra Kachole as Chairperson. At the said meeting, the ECRHS approved the proposal for the clinical study entitled as "Estimation of gestational age from human fetal diaphyseal length of femur."

The ECRHS reviewed and approved the following documents submitted for the above mentioned clinical study.

List of Documents:

1. Study Protocol
2. Informed consent form
3. Case Record form
4. Appendices/Questionnaire
5. Adverse event reporting form / Product monograph
6. Current CV of Principal Investigator
7. Principal Investigator's undertaking

It is policy of ECRHS that, it should be informed about any serious adverse event occurring during the course of the study within seven days of the occurrence of the adverse event. The ECRHS expects to be informed about any changes in the protocol and informed Consent Document and asks to be provided a copy of the final report. The status of the study (completed/ongoing/terminated) should be reported to the ECRHS annually. 12 Members attend the meeting held on 10th Oct., 2019, fulfilling the quorum. It is hereby confirmed that neither you nor any of the study team members have participated in the voting/decision making procedures of the committee.



(Signature)
Dr. Deepali Jaybhaye
Member Secretary
MGM-ECRHS
Department of Pharmacology,
MGM's Medical College, Aurangabad.

Member Secretary
MGM-ECRHS
MGM's Medical College, Aurangabad

INFORMED VOLUNTARILY CONSENT FORM OF PARENTS

Research project title: **Estimation Of Gestational Age From Human Fetal Diaphyseal Length Of Femur**

Principle Investigator – Dr. khan Sana Gaffoor

Research & Development Cell

MGM Institute of Health Sciences, Navi Mumbai

Phone No. 022- 27432471/27432994

Email: ecrhs@mgmuhs.com

Parent's Name

Parent's Name

[Please tick mark the applicable]

1. I confirm that I have read and understood the information of the above mentioned study. ☐
2. I have had the opportunity to consider the information, ask questions and I have received an explanation of the nature, purpose, duration answered satisfactorily. ☐
3. I understand that my participation is voluntary and that I am free to withdraw at any time without giving reasons. ☐
4. I understand that relevant section of any of my personal details and data collected during the study may be looked at by responsible individuals [MGM Medical College- institutional EthicsCommittee] and from regulatory authorities, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my fetal sample. ☐
5. I understand that my identity will not be revealed in any report or publication and I am not entitled for any compensation or otherwise as a part of the study. ☐
6. I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose/s. ☐
7. I voluntarily agree to take part in the above study. ☐

Parent's Name and signature
Date:

Name and signature of Investigator
Date: