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CORRELATION OF GESTATIONAL AGE WITH FETAL FEMORAL THICKNESS IN NORMAL PREGNANCY

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Femur length, Femur thickness, Gestational age

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Abstract

Background: *Assessment of fetal growth is vital in antenatal care for monitoring fetal well-being. Gestational age estimation guides pregnancy evaluation and perinatal management. Although BPD, HC, AC, and FL are commonly used, fetal femoral thickness (FFT) has emerged as a useful additional parameter. Measured at the femoral midshaft, FFT reflects both skeletal and soft-tissue development. It is a simple, non-invasive, and reproducible ultrasound marker, particularly helpful in later trimesters. Correlating FFT with gestational agemay improvegrowth charts and enhance diagnostic accuracy.*

Objective: *To correlate the gestational age with fetal femoral thickness in normal pregnancy.*

Methodology: *This cross-sectional study was conducted in the UOL Ultrasound Clinic Green Town Lahore, over a duration 7 months. This study is based on a convenient sampling technique, and includes a population comprised of normal pregnant females from second trimester till term. Females with abnormal pregnancies were not included in this study.*

Results: *A total of 334 pregnant women with gestational ages ranging from 13 weeks to term and with normal pregnancies were included. The analysis demonstrated a moderate positive correlation between FT/FL and gestational age, with a correlation coefficient (r) of 0.5535. This association was found to be statistically significant ($p < 0.0001$). The 95% confidence interval for the correlation coefficient ranged from 0.4743 to 0.6237.*

Conclusion: *There is a significant moderate positive correlation between FL (mm) and FT (mm) or FT(mm) and gestational age, indicating that femur thickness increases with femur length.*

INTRODUCTION

The longest and strongest bone in the fetus's growing lower limb is the fetal femur. During the early stages of fetal development, it first takes the form of a cartilaginous model before going through an ossification process. Friedman, L. M.et al., (2015) The diaphysis, proximal epiphysis, and distal epiphysis are the three

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sections that make up the bone. About 7 to 8 weeks into the pregnancy, the diaphysis starts to ossify, progressively becoming a strong, tubular structure that will maintain the bone's length. The medullary cavity, which will eventually hold bone marrow, is located in this middle shaft. Agarwal, P et al.,(2023) The epiphyses are located at either end of the femur and remain mainly cartilaginous during fetal life. The proximal epiphysis comprises the femoral head, neck, and greater trochanter, which will later articulate with the pelvis at the hip joint. The distal epiphysis is the portion of the femur that connects to the knee joint. Alsarraf, F. et al., (2025) The metaphysis, which is located between the diaphysis and each epiphysis, contains the growth plates, which are composed of cartilage and give the femur its lengthwise growth during fetal and childhood. Alsarraf, F. et al.,(2009)

Fig 1: Anatomy of femoral bone (Soubeyrand, M., et al., 2020)

The femur first develops from a cartilage template by a process known as endochondral ossification, in which bone progressively replaces cartilage. The major ossification center in the diaphysis (shaft) appears during the seventh or eighth week of fetal life, marking the start of this process. Ossificationcenter as the fetus develops, enabling the bone to solidify while retaining the degree of flexibility required for fetal movements. Marenzana et al.,(2013) Growth of the fetal femur primarily occurs at the growth plates located in the metaphysis between the diaphysis and the epiphyses. Proliferating chondrocytes in these cartilaginous growth plates divide and increase, pushing the bone lengthwise and enabling the femur to elongate in tandem with the fetal growth as a whole. In order to ensure appropriate development in relation to the rest of the fetus, this longitudinal growth is strictly controlled by hormonal and genetic variables. Szabo et al., (2013)

Nutrient arteries that deliver oxygen and nutrients necessary for the active metabolism of bone-forming cells are abundantly vascularized throughout the embryonic femur. The elimination of waste materials produced during rapid bone turnover is also aided by this venous supply. The femur's physiological function also involves supporting the growing lower limb structurally and enabling fetal movement, both of which are critical stimuli for healthy musculoskeletal development. Leung et al.,(2021)

High-frequency sound waves are used in ultrasound, a medical imaging method, to produce images of internal body structures. Sound waves are emitted by a device known as a transducer; these waves travel through the body and return when they strike certain tissues or organs. Filly et al., (2007) A computer then records and transforms these reflected sound

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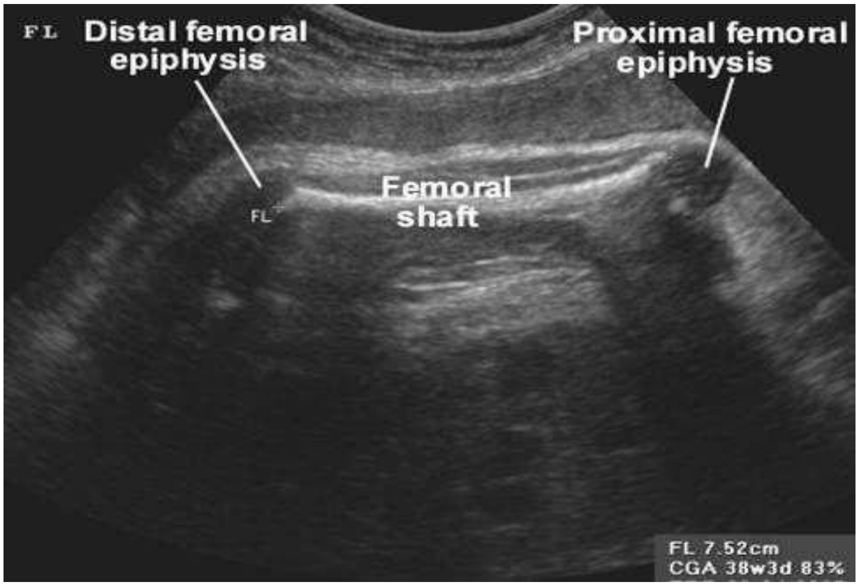
waves into live visuals. Because ultrasound is radiation-free, non- invasive, and safe, it is employed extensively. It is particularly helpful in obstetrics for diagnosing different disorders, guiding medical operations, monitoring fetal development, and evaluating organ health. Ultrasound is a vital tool in modern medicine since it allows for the viewing of live images. Debbink et al., (2021)

On ultrasound, the fetal femur appears as a long, bright (echogenic) linear structure with well-defined edges. It is usually seen as a straight, bright line representing the femoral shaft, while the ends of the bone appear slightly rounded. Allan et al., (2011) The femur is surrounded by softer, darker (hypoechoic) tissues, which help distinguish it clearly from the surrounding structures. In obstetric ultrasound, the femur length is measured from one end of the bone to the other, excluding the epiphyses, to help estimate gestational age and assess fetal growth. As the pregnancy progresses, the femur becomes more prominent and easier to identify due to increasing bone calcification, which enhances its brightness on the ultrasound image. Llanes et al.,(2025) The fetal femur can usually be visualized by 12–13 weeks of gestation using a high-resolution transabdominal or transvaginal ultrasound. It becomes clearly visible after 14 weeks, and femur length measurement is routinely performed from 14 weeks onward until term. (Korber, et al., 2005).



Obstetric ultrasound image showing the fetal femur (thigh bone) Seeds, J. W. (1996).

In order to measure the fetal femur on ultrasound, a clean longitudinal image of the femur that displays the full length of the ossified diaphysis must be obtained. To avoid foreshortening or oblique angles that could understate the length, the ultrasonic transducer is positioned to view the femur in its longest axis. (Uduma,et al, 2020). To measure the femur length, calipers are positioned at the two distal ends of the ossified shaft, from the greater trochanter area proximally to the distal metaphysis close to the knee. Because cartilage is difficult to see on ultrasonography, the measurement primarily looks at the ossified diaphysis and ignores the cartilaginous ends (epiphyses). To assess fetal age and growth status, the length of the femur is measured in millimeters or centimeters and compared to established gestational age charts. (Jain,et al., 2021).

The fetal femur, as a key component of the developing skeletal system, can be affected by a variety of pathologies that may impact fetal growth and development. These conditions range from growth limits brought on by genetic disorders or intrauterine causes to congenital abnormalities such skeletal dysplasias and limb

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deformities. (Tonni, et al., 2016) Femur length or structure abnormalities found during prenatal ultrasonography can be significant indicators of chromosomal disorders, fractures, or dwarfism, among other underlying diseases. For proper prenatal counseling, management, and postnatal care planning, early detection of fetal femur diseases is essential. Leung et al.,(2021)

Campomelic femur is defined as a congenital bowing or curvature of the femur, usually seen as part of campomelic dysplasia, a rare skeletal dysplasia. (Korber, et al., 2005). Proximal femoral focal deficiency (PFFD) is a rare congenital anomaly of the femur characterized by partial absence, hypoplasia, or malformation of the proximal femur, leading to a shortened thigh, hip deformity, and limb length discrepancy. (Uduma,et al, 2020)

Figure 3: Panda A et al. World J Radiol. 2014;6(10):808–825.

Femoral hypoplasia of the fetus is defined as a congenital underdevelopment of the femur detected prenatally, where the femoral length measures significantly below the expected value for gestational age (usually below the 5th or 10th percentile), indicating an abnormally short or small thigh bone. (Jain,et al., 2021). Femoral bowing of the fetal femur is defined as an abnormal curvature or angulation of the femoral shaft detected on prenatal ultrasound, instead of the normal straight alignment of the femur. (Tonni, et al., 2016)

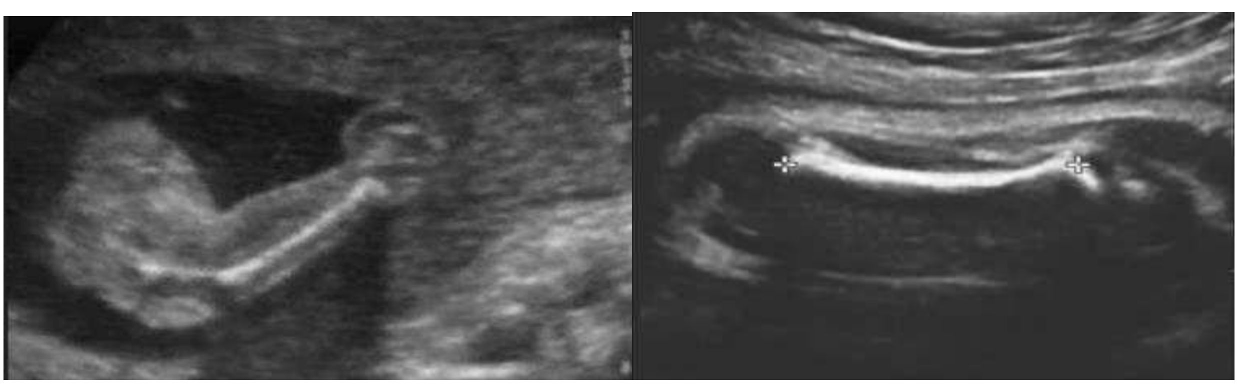

Figure 4: Obstetric ultrasound image showing femoral hypoplasia–unusual facies syndrome in the fetus. Paladini, D. Maruotti et al (2007)

The rationale behind this study is to make a correlation of gestational age with femoral length and femur thickness in normal pregnancy from 13th week till term. Among the various parameters, fetal femur length (FL) has been extensively studied and is widely used as a reliable

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indicator for estimating gestational age and identifying abnormalities. However, despite the critical importance of skeletal measurements, the literature lacks comprehensive studies focusing on fetal femur thickness (FT). Considering the potential of femur thickness to serve as an additional marker for assessing fetal growth, this study seeks to address the gap by exploring the significance of FT as a complementary parameter. Investigating this dimension could enhanced diagnostic precision, particularly in cases of skeletal dysplasia or growth restriction, where thickness measurements may provide unique insights not captured by length alone. By filling this gap, the study aims to contribute valuable data that could enrich the field of fetal biometry and improve clinical outcomes.

MATERIALS AND METHODS

A cross-sectional study design was employed to assess fetal biometric parameters. Data were collected from the Radiology Department, University Ultrasound Clinic, Green Town Lahore over a period of seven months. The study included pregnant women aged 22–35 years with gestational age ranging from 13 weeks to term. Sampling was carried out using a convenient sampling technique, and all eligible patients presenting within four months after approval of the synopsis were included as the study sample. Women in the first trimester and those with any underlying medical or obstetric disease were excluded to minimize confounding effects on fetal measurements. Ultrasound examinations were performed using a Toshiba Xario XG machine equipped with a convex probe (3–5 MHz) to ensure high-resolution fetal imaging and accurate biometric assessment.

Data were recorded using structured data collection sheets and included both qualitative and quantitative variables, specifically fetal femur length and femoral thickness measurements. Standardized ultrasound scanning protocols were followed by trained sonographers. Patients were positioned supine, and a conductive gel was applied over the abdomen. Measurements were obtained in transverse and longitudinal planes after identifying key fetal anatomical landmarks, including biparietal diameter and abdominal circumference, followed by localization of the femoral shaft. Femoral thickness was measured at the widest point perpendicular to the long axis in millimeters using electronic calipers. Data were analyzed using MedCalc version 20.215. Descriptive statistics were applied for all variables, with continuous data expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Student's t-test was used for group comparisons, and a p-value < 0.05 was considered statistically significant.

RESULTS

TABLE NO .1

	N	Minimum	Maximum	Mean	Median
Age(years)	334	20.000	35.000	26.958	27.000
Weeks	334	12.000	38.000	27.832	29.000

Table no 1 shows total number of patients 334 with maximum and minimum age of patients age and gestational age are 20, 35 and 12,38 respectively

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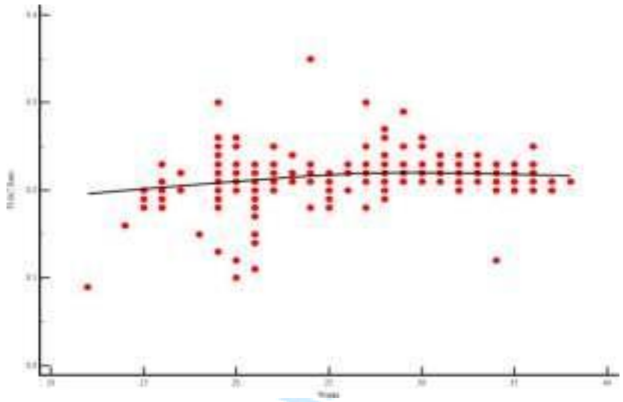
TABLE NO. 2

Variable Y	FL_AC_Ratio FL/AC Ratio
Variable X	Weeks
Sample size	334
Correlation coefficient r	0.2671
Significance level	P<0.0001
95% Confidence interval for r	0.1645 to 0.3640

Table no 2 shows the ratio between FL/ AC with weeks and the sample size was 334 the correlantion coefficient **r** value is 0.2671, and the P value is significant which is <0.0001 and the confidence interval for r is in between 0.1645- 0.3640

GRAPH 1



This graph shows ratio between FL/ AC with weeks

TABLE NO.3

Variable Y	FL_BPD_Ratio FL/BPD Ratio
Variable X	Weeks
Sample size	334
Correlation coefficient r	0.4782
Significance level	P<0.0001
95% Confidence interval for r	0.3910 to 0.5570

Table no 3 shows the ratio between FL/ BPD with weeks in a sample size that was 334 the correlation coefficient **r** value is 0.4782, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.3910- 0.5570.

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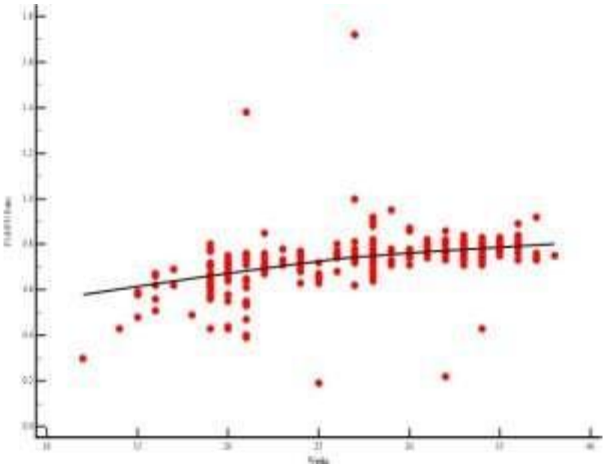
GRAPH 2



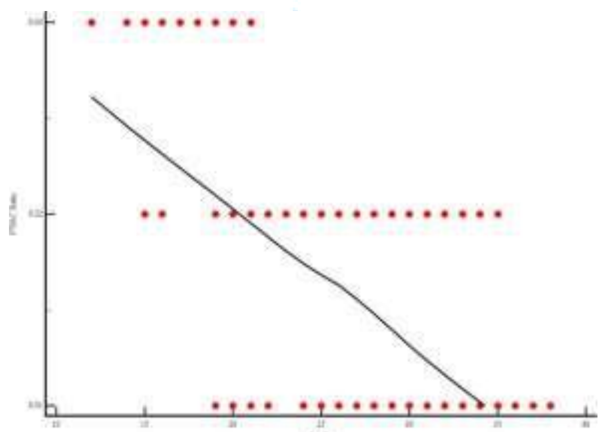
This graph shows ratio between FL/ BPD with weeks.

TABLE NO. 4

Variable Y	FT_AC_Ratio FT/AC Ratio
Variable X	Weeks
Sample size	334
Correlation coefficient r	-0.6227
Significance level	P<0.0001
95% Confidence interval for r	-0.6843 to -0.5523

Table no 4 shows the ratio between FT/ AC with weeks in a sample size was 334 the correlation coefficient **r** value is -0.6227, value P value is significant which is <0.0001 and the confidence interval for r is in between -0.6843 to -0.5523

GRAPH 3



This graph shows ratio between FT/AC with weeks.

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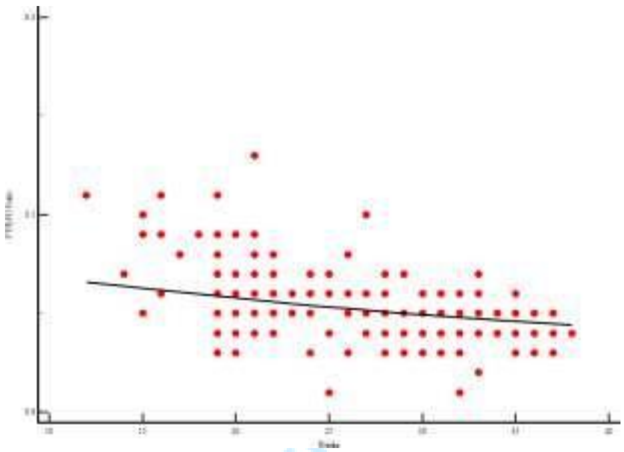
TABLE NO. 5

Variable Y	FT_BPD_Ratio FT/BPD Ratio
Variable X	Weeks
Sample size	334
Correlation coefficient r	-0.4789
Significance level	P<0.0001
95% Confidence interval for r	-0.5576 to -0.3917

Table no 5 shows the ratio between FT/ BPD with weeks in a sample size was of 334 patients the **r** value is -0.4789, value of P is significant which is <0.0001 and the confidence interval for r is in between -0.5576 to –0.3917.

GRAPH 4



This graph shows ratio between FT/BPD with weeks

TABLE NO. 6

Variable Y	FT_Ratio FT Ratio
Variable X	Weeks
Sample size	334
Correlation coefficient r	-0.6323
Significance level	P<0.0001
95% Confidence interval for r	-0.6926 to -0.5632

Table no 6 shows the ratio between FT with weeks in a sample size was 334 the correlation coefficient **r** value is -0.6323, value of P is significant which is <0.0001 and the confidence interval for r is in between -0.6926 to –0.5632.

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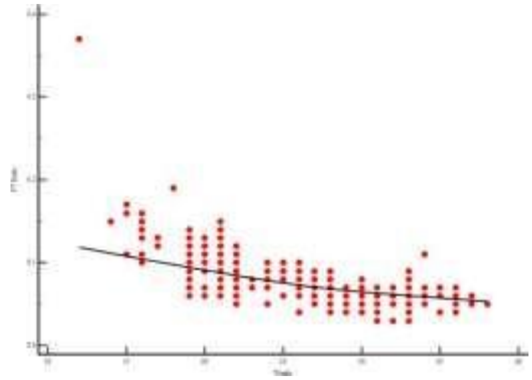
GRAPH 5



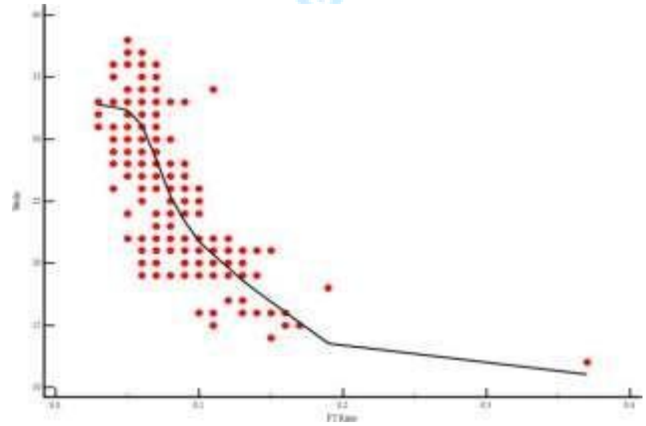
This graph shows between FT with weeks.

TABLE NO. 7

Variable Y	FT_mm_ FT(mm)
Variable X	Weeks
Sample size	334
Correlation coefficient r	0.5609
Significance level	P<0.0001
95% Confidence interval for r	0.4826 to 0.6303

Table no 7 shows the relation between FT with weeks in a sample size was 334 the correlation coefficient r value is -0.5609, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.4826 to 0.6303

GRAPH 6



This graph shows ratio between FT with weeks.

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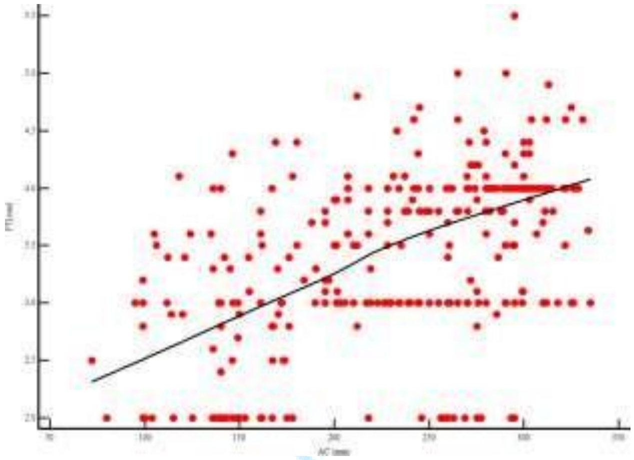
TABLE NO. 8

Variable Y	FT_mm_ FT(mm)
Variable X	AC_mm_ AC (mm)
Sample size	334
Correlation coefficient r	0.5374
Significance level	P<0.0001
95% Confidence interval for r	0.4564 to 0.6096

Table no 8 shows the relation between FT/AC with weeks in a sample size was 334 the correlation coefficient r value is 0.5374, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.4826 to 0.6096

GRAPH 7



This graph shows ratio between FT with AC.

TABLE NO. 9

Variable Y	FT_mm_ FT(mm)
Variable X	BPD_mm_ BPD(mm)
Sample size	334
Correlation coefficient r	0.4234
Significance level	P<0.0001

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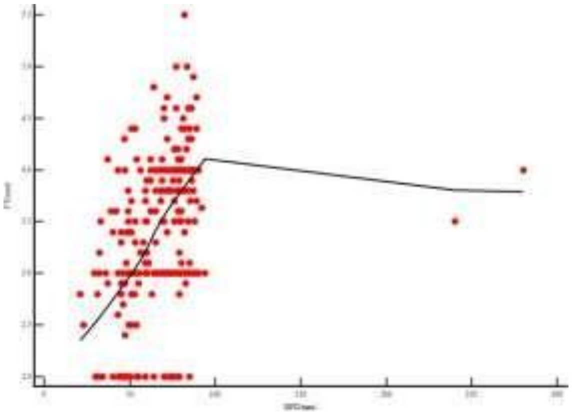
GRAPH 8



This graph shows ratio between FT with BPD.

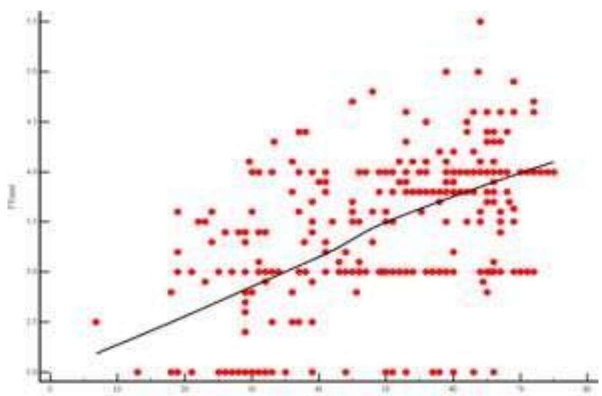
Table no 9 shows the relation between FT/BPD with weeks in a sample size that was 334 the correlation coefficient r value is 0.4234, value of P is significant which is <0.0001

TABLE NO. 10

Variable Y	FT_mm_ FT(mm)
Variable X	FL_mm_ FL(mm)
Sample size	334
Correlation coefficient r	0.5535
Significance level	P<0.0001
95% Confidence interval for r	0.4743 to 0.6237

Table no 10 shows the relation between FT/FL with weeks in a sample size was 334 the correlation coefficient r value is 0.5535, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.4743 to 0.6237

GRAPH 9



This graph shows ratio between FT with FL.

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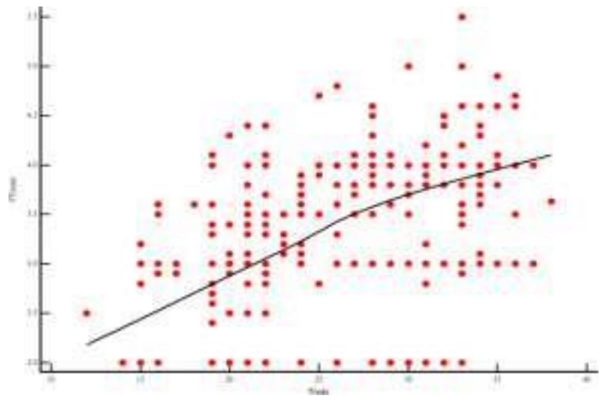
GRAPH 10



This graph shows relation between FT with weeks

CHAPTER 6
DISCUSSION

In prenatal care, fetal growth assessment is essential for tracking the health of the fetus. Pregnancy assessment and perinatal care are guided by gestational age estimation. Fetal femoral thickness (FFT) has become a helpful extra metric, despite the fact that BPD, HC, AC, and FL are frequently employed. FFT, which is measured at the midshaft of the femur, represents both soft-tissue and skeletal development. It is a straightforward, repeatable, non-invasive ultrasonography marker that is especially useful in the later stages of pregnancy. Growth charts and diagnostic precision may be improved by correlating FFT with gestational age.

A total of 334 pregnant women with gestational ages ranging from 13 weeks to term and with normal pregnancies were included. The analysis demonstrated a moderate positive correlation between FT/FL and gestational age, with a correlation coefficient (r) of 0.5535. This association was found to be statistically significant ($p < 0.0001$). The 95% confidence interval for the correlation coefficient ranged from 0.4743 to 0.6237.

Roisin Daly et al., conducted a study in January 2020 on the topic of Femur length ratios as predictors of adverse outcome in fetuses to determine whether femur length, used in a ratio with head biometry, is a better predictor of adverse outcome than abdominal circumference in small for gestational age (SGA) pregnancies. They found the ratios of FL/HC, FL/BPD&AC/HC to be significant predictors of adverse perinatal outcome. There were moderate correlations between all the ratios(r>0.4), with the strongest correlation between FL/HC and FL/BPD (r¼0.87). They concluded that the FL/HC ratio is the strongest and earliest predictor of adverse outcome in SGA pregnancy and can be used to identify at risked fetuses. Our study shows the ratio between FL/ BPD with weeks in a sample size that was 334 the correlation coefficient r value is 0.4782, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.3910-0.5570 and the relation between FT/FL with weeks in a sample size was 334 the correlation coefficient r value is 0.5535, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.4743 to 0.6237.

Sumit Babutaa et al., conducted a study on the topic Assessment of fetal gestational age in different trimesters from ultrasonographic measurements of various fetal biometric parameters in 2013. The study was carried out to assess gestational age in the second and third trimesters with the help of ultrasonographic measurements of four fetal biometric parameters (i.e., biparietal diameter [BPD], head circumference [HC], abdominal circumference [AC], and femur length [FL]) in the local population of Rajasthan. Three hundred and thirty cases of normal pregnant females were studied (165 –second trimester [13–28weeks] and165 – third trimester [29–40 weeks]) with the known last menstrual period (LMP) and studied

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once during gestation and BPD and FL in the third trimester. Abdominal circumference was the least accurate parameter in both trimesters. Variability in predicting gestational age (using all four parameters) was ±2 weeks in the second trimester and +2 to 4 weeks in the third trimester. They concluded that the variation in predicted gestational age by ultrasonography (USG) was attributed to the anthropometric difference between the two populations due to racial, genetic, nutritional, and socioeconomic factors .Our study shows the ratio between FL/ AC with weeks and the sample size was 334 the correlation coefficient r value is 0.2671, and the P value is significant which is <0.0001 and the confidence interval for r is in between 0.1645- 0.3640 and shows that the relation between FT/FL with weeks in a sample size was 334 the correlation coefficient r value is 0.5535, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.4743 to 0.6237.

Dr. Sandhya ani M. Parietal., conducted a study on the topic, The Study of Assessment of Gestational Age from Fetal Femur Length by Ultrasonography in 2019. This prospective cross-sectional study consisted of 150 normal antenatal women. As a result, the gestational age predicted from the femur length measurements of 1223 subjects from 13 to 40 weeks were presented. There was a gradual increase of the femur length measurements from 13 to 27 weeks gestation. Our study shows the ratio between FL/ AC with weeks and the sample size was 334 the correlation coefficient r value is 0.2671, and the P value is significant which is <0.0001 and the confidence interval for r is in between 0.1645- 0.3640 and the relation between FT/FL with weeks in a sample size was 334 the correlation coefficient r value is 0.5535, value of P is significant which is <0.0001 and the confidence interval for r is in between 0.4743 to 0.6237.

CHAPTER 7 CONCLUSION

There is a significant moderate positive correlation between FL (mm) and FT (mm) or gestational age and FT (mm), indicating that femur thickness increases with femur length.

7.2: RECOMMENDATIONS

- Including participants from varied geographical regions will prevent findings from being limited to a single institution, thereby broadening the scope of the study.
- It is recommended that further research be conducted on patients with specific diseases or medical conditions. Including such participants in future studies would provide a broader understanding of the topic and help determine whether the results observed in normal patients are consistent across different clinical populations.
- The inclusion of data from various clinical centers can account for variations in imaging techniques, equipment standards, and operator expertise, further enhancing the reliability of the study outcomes.

7.3: LIMITATIONS

1. The sample size was relatively small, limiting the generalizability of the results.
2. Duration of study was small.
3. We have used convenient sampling, which may have introduced selection bias, limiting generalizability.
4. Furthermore, all participants in the study were normal patients, which reduced the variability in the sample and may have influenced the outcomes.
5. Operator dependency of ultrasound could influence measurements, and inter-observer variability was not assessed.

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