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SYED SAMI AHMAD SAMAR BUKHARI

SU91-MSAHW-S23-141

FAHS

Correlation of Fetal Renal Volume with Gestational Age and Fetal Weight in 3rd Trimester Ultrasound



SUPERIOR UNIVERSITY

Thesis Submitted to

The Superior University Lahore

In Partial Fulfillment of the

Requirement for the Degree of

Master of Science in Allied Health Sciences

By

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Roll No. SU91-MSAHW-S23-141

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Hafiz Ayaz Ahmad
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No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Faculty of Allied Health Sciences, The Superior University, Lahore in partial fulfillment of the requirements for the degree of Master of Science in the field of **“Allied Health Sciences”** in Faculty of Allied Health Sciences at The Superior University, Lahore.

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DEDICATION

This thesis is dedicated to my parents, whose unconditional love, support, and belief in me have been the foundation of my journey. Their encouragement has been a constant source of strength, and their sacrifices have motivated me to push beyond my limits. To my teachers, who have imparted their knowledge, wisdom, and passion for learning, I am deeply grateful for their guidance and the inspiration they have provided throughout my academic journey. I would also like to express my sincere gratitude to my supervisor **Hafiz Ayaz Ahmad**, whose expert advice, patience, and unwavering support have been instrumental in shaping this research. This thesis is a reflection of the invaluable contributions of all those who have been a part of my academic and personal growth.

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In the name of Allah, the most Gracious, the most Merciful.

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LIST OF ABBREVIATIONS

BP	Blood Pressure
IUGR	Intrauterine growth restriction
2D	Two-Dimensional
3D	Three-Dimensional
PI	Pulsatility index
RI	Resistance index
FKL	Fetal kidney length
BPD	Biparietal diameter
AC	Abdominal circumference
HC	Head circumference
FL	Femur length
LGA	Large-for-gestational-age
FRV	Fetal Renal Volume
SPSS	Statistical Package for the Social Sciences

ABSTRACT

Background: Fetal renal volume is a critical parameter in assessing fetal growth and development. This study investigates the correlation between fetal renal volume, gestational age, and fetal weight during the third trimester of pregnancy.

Methods: We studied a total of 385 pregnancies from the third trimester. For each case, maternal gestational age, fetal weight, and right and left kidney volumes were captured in descriptive statistics. A correlation analysis was performed to investigate the relationships between the volumetric parameters of the kidney and the age and weight of the fetus. Renal volumetric data was examined for predictive modeling based on children's age and weight.

Results: Descriptive statistics showed right and left kidney volumes of means 7.54 cm³ and 7.55 cm³ while standard deviation was 2.14 and 2.16, respectively. The average weight of the fetus was 2332.14 grams (SD = 762.42), and the average gestational age was 33.58 weeks (SD = 3.52). There were strong positive associations discovered: Gestational age ($r=0.948$) and fetal weight ($r=0.938$) represent the right kidney volume. Gestational age ($r=0.950$) and fetal weight ($r=0.943$) represent the left kidney volume. Regression modeling revealed: 92.6% of kidney volume variance explained by gestational age ($R^2=0.926$; $p < 0.001$). 90.9% of kidney volume variance explained by fetal weight ($R^2=0.909$, $p < 0.001$).

Conclusion: Prenatal kidney volume is a good measure of fetus development and growth since it has a high correlation with both fetal weight and gestational age. The usefulness of ultrasound in tracking fetal development throughout the third trimester was highlighted by regression models' strong prediction ability.

Keywords: Fetal kidney volume, gestational age, fetus weight, ultra-sonography, 3rd trimester, embryonic development, prenatal valuation.

Chapter 1

INTRODUCTION

Fetal development is a complex and dynamic process that unfolds throughout pregnancy. During this critical stage, numerous organs undergo significant maturation, laying the foundation for survival and function after birth. The concept that prenatal factors influencing fetal growth and development can cause long-term alterations in organ structure or function or both is known as developmental programming, also referred to as fetal programming [1].

These alterations are associated with an increased risk of various chronic disorders later in life and even across generations. These include metabolic syndrome, growth abnormalities, as well as immunological, behavioral, cognitive, and reproductive dysfunctions [2]. Dr. David Barker and colleagues introduced the concept of developmental programming using epidemiological evidence to demonstrate a strong link between low birth weight, poor postnatal conditions, and other developmental insults such as exposure to stress-related hormones like corticosteroids and the later onset of such disorders. These findings have since been validated by numerous epidemiological studies in humans and controlled studies in animals [3].

The third trimester of pregnancy is especially critical, marking the final phase of organ development and substantial fetal weight gain. Among the vital organs, the kidneys play a crucial role in regulating amniotic fluid levels and excreting metabolic waste. Kidneys, as part of the urinary system, also help regulate blood sugar and blood pressure and function as endocrine organs by secreting substances like kinins, erythropoietin, renin, and 1,25-dihydroxycholecalciferol. Optimal neonatal outcomes depend on the normal development of fetal kidneys, and knowledge of the expected size of the kidneys, adrenal glands, and renal pelvis is essential for identifying abnormalities [4].

Accurately assessing fetal age and development is especially important in high-risk pregnancies. The development of the urinary system has unique features throughout fetal life. Three stages of kidney development occur; two regress over time, while the final form remains permanent. Understanding the growth and developmental trajectory of the kidneys is critical for assessing fetal health. Abnormal development

or organ function can lead to severe complications such as intrauterine growth restriction (IUGR) or congenital anomalies [5].

During the first trimester (weeks 1–12), all major organ systems begin forming—a phase known as organogenesis. Although still immature, the kidneys begin to develop. Fetal development during this period is relatively slow and marked by early cell differentiation. The second trimester (weeks 13–26) is characterized by rapid organ growth [6].

By the early second trimester, the fetus starts producing urine, contributing to amniotic fluid volume. Kidney cells begin forming distinct structures. By the start of the third trimester, kidneys can perform basic functions, though some capacities are still developing. This phase is vital for fetal assessment, as biometric parameters—such as biparietal diameter, femur length, and abdominal circumference—are routinely used to estimate fetal size. Organ maturation continues throughout the third trimester, with the fetus gaining the most weight and reaching functional maturity. Monitoring fetal health is especially critical during this time since survival outside the womb depends heavily on organ readiness. Kidney anomalies, including structural or functional defects, can be detected through non-invasive imaging, primarily ultrasonography [7].

Kidneys grow in proportion to overall fetal development and typically reach their mature size by the third trimester. The increase in renal capacity equips the fetus for postnatal physiological demands. Kidney size reflects overall fetal growth since renal volume correlates strongly with gestational age and fetal weight. Numerous studies confirm a marked increase in renal volume during this stage, and ultrasonographic measurement of kidney size can provide critical insights into fetal health [4].

Most kidney cells responsible for excretory function are formed by 4–5 months of gestation. No new nephrons develop after this point, which determines the renal functional potential at birth. By the third trimester, the kidney's outer (cortex) and inner (medulla) regions become distinguishable. The cortex, housing the glomeruli, becomes more prominent, while the medulla—essential for urine concentration—continues to develop. These structures are vital for maintaining electrolyte and fluid balance after birth [8].

By late pregnancy, the fetus produces around 500–700 mL of urine daily into the amniotic sac. This urine production is essential for maintaining optimal amniotic fluid levels, which support fetal movement and pulmonary development. Kidney function reaches near-maximum capability by the third trimester, although some functions continue maturing after birth. Both oligohydramnios (low fluid) and polyhydramnios (excess fluid) can signal underlying fetal renal or systemic problems [8].

Fetal kidneys filter metabolic waste and regulate electrolytes such as sodium and potassium in the third trimester. Although waste elimination is primarily handled by the placenta, renal function becomes increasingly important as the fetus prepares for independent life [9].

Weight gain is most pronounced during the third trimester, with the fetus typically gaining 2.5–3 kg by term. This growth supports postnatal energy storage, thermoregulation, and metabolism. Musculoskeletal growth enhances fetal mobility, which can be monitored to assess well-being. Significant brain development also occurs, contributing to increased head circumference. Neurological maturation enables essential postnatal functions like breathing, feeding, and thermoregulation [10].

Fetal growth and kidney development are influenced by maternal, placental, and genetic factors. These elements ensure that the fetus reaches appropriate weight milestones and that critical organs, including the kidneys, achieve functional maturity [11].

For example, maternal hyperglycemia can lead to fetal hyperinsulinemia, resulting in macrosomia and disproportionately large kidney size. However, gestational diabetes can also impair organ maturation, possibly compromising kidney function after birth [12].

Conditions like pre-eclampsia can reduce uteroplacental blood flow, restricting the nutrient supply necessary for fetal growth. This can result in IUGR and lower renal volume and nephron number—factors associated with long-term renal insufficiency [13].

Inadequate maternal nutrition and placental dysfunction can similarly reduce fetal renal volume, increasing the risk of postnatal renal complications. Structural kidney

anomalies (e.g., renal agenesis or polycystic kidney disease) and certain genetic mutations can also compromise renal development and are associated with lower birth weight and increased risk of chronic kidney disease. Therefore, kidney volume growth—closely linked to fetal weight and gestational age—is influenced by maternal, placental, and genetic variables [14].

Imaging techniques, primarily ultrasound, are essential in evaluating critical fetal organs including the brain, heart, lungs, and kidneys. These tools allow for early anomaly detection and timely intervention, thereby supporting normal fetal growth and viability [15].

Fetal growth assessment via ultrasonography includes parameters like head circumference, femur length, abdominal circumference, and biparietal diameter. These are used to estimate fetal weight, a key health indicator. Deviations may signal conditions like IUGR, which increases the risk of perinatal morbidity, mortality, and long-term complications. Early identification allows for timely intervention [16].

The kidneys are crucial for fetal health—facilitating waste disposal, fluid balance, and growth. Their development can be evaluated in the third trimester via ultrasonography, allowing healthcare providers to detect and manage conditions such as hydronephrosis or monitor amniotic fluid levels in cases of oligohydramnios [17].

There is a well-established correlation between renal volume and fetal weight. Larger fetuses tend to have proportionately larger kidneys. This association underscores the adaptive growth of renal tissue in response to metabolic demands. In contrast, IUGR often presents with smaller kidney volume and reduced nephron number—factors linked to future cardiovascular and renal disorders like hypertension and chronic kidney disease [19].

Assessing renal volume in relation to fetal weight offers valuable information about fetal well-being and postnatal outcomes. Ultrasound remains the primary, non-invasive tool for this purpose. Deviations from expected norms may warrant further evaluation or intervention. Regular third-trimester ultrasonography is thus essential to assess fetal kidney development and ensure optimal neonatal outcomes [20].

This study underscores the importance of understanding fetal renal development during the third trimester and its relationship to fetal weight and gestational age. The findings may help establish clinical reference standards for assessing renal function

and development, thereby improving prenatal care and enabling early intervention. Additionally, the outcomes may enhance the accuracy of prenatal imaging and advance ultrasound techniques.

AIM & OBJECTIVES

- To correlate the association between renal volume of fetus with gestational age and weight in 3rd trimester of pregnancy in Pakistani pregnant females.

Chapter 2

REVIEW OF LITERATURE

In the third trimester of pregnancy, the evaluation of renal volume is a critical component of prenatal care. As gestational age advances, the kidneys undergo significant growth and maturation, which can be reliably quantified using ultrasonography. This growth reflects overall fetal health and is essential for ensuring normal renal function after birth [1,8].

Ultrasound expertise is essential for accurately measuring kidney volumes and assessing renal structure. The ability to visualize fetal kidneys as early as four months of gestation has greatly enhanced our understanding of renal development and its relevance to fetal well-being [1]. A well-established association exists between increasing gestational age and renal volume, attributed to both an increase in the number and size of renal cells [2,6].

Numerous studies have focused on the correlation between fetal renal volume and gestational age. One study demonstrated that renal length is a reliable indicator of gestational age. This finding is consistent with other research emphasizing the significance of kidney length in determining gestational age, particularly during the late second and third trimesters [4–6].

Extensive research also supports a strong relationship between fetal weight and renal volume. In preterm infants with very low birth weight, renal volume has been proposed as a surrogate marker for nephron number, indicating both renal function and developmental status. One study [5] found a significant association between estimated fetal weight and renal volume, further suggesting that maternal physiological conditions during pregnancy can directly influence fetal growth parameters [6].

The clinical utility of renal parameters in detecting intrauterine growth restriction (IUGR) has been emphasized by studies comparing renal volume in growth-restricted and normally developing fetuses. These studies used advanced 3D ultrasound techniques to measure renal volume more precisely than traditional 2D methods, demonstrating their superior accuracy [7].

Throughout gestation, the size and shape of the fetal kidneys change. The renal

surface becomes smoother, which may reflect structural or functional changes. Identifying normal morphological changes is essential for detecting potential abnormalities and understanding fetal development [8].

Doppler ultrasound has enhanced our understanding of fetal renal function. One study assessed the relationship between fetal renal artery Doppler indices and kidney size in growth-restricted fetuses. The findings revealed that increased arterial resistance might reduce fetal urine output, thereby affecting amniotic fluid volume and reflecting renal function and overall fetal health [10].

Current literature shows a strong correlation among prenatal kidney size, fetal weight, and gestational age. Improved ultrasound technology now permits detailed monitoring of fetal renal development, which is essential for managing high-risk pregnancies. Kidney size has proven to be a dependable indicator for estimating gestational age [11].

Research using 3D ultrasound further supports that renal parenchymal volume increases significantly with advancing gestational age [12]. Several studies confirm that fetal kidney measurements via 3D ultrasound can provide valuable insights for estimating fetal weight [14]. Compared to 2D imaging, 3D ultrasound offers more precise kidney volume estimates by avoiding the limitations of linear measurements [13].

Accurate fetal weight estimation is essential for identifying growth restrictions and planning effective interventions. Studies have shown that 3D limb volume models can enhance the precision of fetal weight estimation in the third trimester and subsequently improve clinical outcomes [15]. Greater renal volumes generally indicate better fetal development, underscoring the strong association between renal size and fetal weight [16].

Doppler ultrasonography also allows for assessment of renal blood flow and vascular resistance, supplementing volumetric evaluations. Doppler indices, such as the resistance index and pulsatility index, correlate with renal volume and can reveal potential dysfunction in fetuses with growth restriction [17].

Renal evaluation in prenatal care is critical for distinguishing between healthy and growth-restricted fetuses. Understanding the associations among fetal renal volume, gestational age, and fetal weight enables better risk management. Detecting low

renal capacity and reduced fetal weight can prompt closer monitoring and early intervention. The use of 3D ultrasound significantly improves assessments of fetal development and benefits both maternal and fetal outcomes [18–19].

As gestational age progresses, fetal renal volume increases substantially. Studies consistently show a positive correlation between renal volume and gestational age, reinforcing the idea that kidney size reflects overall fetal development. Since fetal urine plays a role in regulating amniotic fluid levels, abnormalities in kidney growth may signal underlying health concerns [21–22].

In cases such as hydronephrosis, fetal kidney health can be evaluated effectively by measuring renal parenchymal volume via ultrasonography [23]. Compared to conventional 2D techniques, ultrasonography now provides more precise measurements of embryonic kidney volume, thanks to advancements in imaging technology [24]. This is particularly important for identifying fetuses at risk of developmental disorders. For instance, growth-restricted fetuses often have reduced renal volumes, which may suggest underlying pathology [27].

Fetal weight is closely related to renal volume, as both parameters represent the overall growth of the fetus. Larger renal volumes are frequently observed in heavier fetuses, particularly in the third trimester, highlighting renal volume as a reliable marker for fetal weight [25,26].

Fetal renal development is influenced by fetal weight, kidney volume, and maternal/environmental factors. Maternal conditions such as gestational diabetes and hypertension have been shown to alter fetal growth patterns, including kidney development [30–31]. External influences like maternal nutrition and environmental exposures also play a role in shaping renal growth trajectories [32].

Doppler ultrasound has become a powerful tool in evaluating fetal kidney health. Researchers have employed Doppler indices to measure renal blood flow and examine its association with renal function and fetal growth [33].

There is a well-recognized relationship between fetal weight and renal volume. Since both reflect the fetus's growth trajectory, studies indicate that larger kidney volumes are often associated with higher fetal weights. Renal volume measurements can therefore help predict fetal weight, especially in cases of suspected growth restriction [36]. Recognizing this association is vital for identifying growth-related

complications and planning appropriate management strategies [37].

The development of 3D ultrasonography has significantly improved the evaluation of fetal renal volume. It enables better visualization and quantification of renal parenchymal tissue, which can help predict postnatal renal function in fetuses with congenital anomalies [38]. Maternal factors—such as gestational age and fetal weight—also strongly influence fetal renal development. Maternal health conditions like diabetes and hypertension may negatively impact both fetal growth and kidney development [10,11].

Poorly controlled maternal diabetes is a major risk factor for large-for-gestational-age fetuses, potentially leading to abnormal fetal development and increased renal volume [39]. Doppler ultrasonography adds further value by offering insights into renal blood flow, which is essential for evaluating renal function and its relationship to fetal growth [33]. A strong correlation exists between renal blood flow and renal volume, particularly in both normal and growth-restricted fetuses [40].

Chapter 3

METHODOLOGY

3.1 Research Design:

A hospital-based cross-sectional study was conducted to evaluate gestational age in the third trimester by measuring fetal renal volume and estimated fetal weight.

3.2 Setting:

Data collection occurred at Samar Diagnostic Laboratory, Baghbanpura, Lahore. All third-trimester pregnant women referred for routine obstetric ultrasound during the study period were considered for enrolment.

3.3 Sample Size:

Using the Fisher formula to calculate the sample size.

Confidence Level (Z): Typically, 95% confidence level is used, corresponding to a Z value of 1.96.

Proportion (p): If no previous study is available, a proportion of 0.5 (50%) is used to maximize the sample size.

Margin of Error (d): Commonly used margins of error are 0.05 (5%).

Fisher Formula for Sample Size Calculation:

$$n = Z^2 \times p \times (1-p) / d^2$$

- **n** is the sample size,
- **Z** is the Z value (1.96 for 95% confidence),
- **p** is the estimated proportion (0.5 if unknown),
- **d** is the margin of error (0.05).

Calculation:

$$n = (1.96)^2 \times 0.5 \times (1-0.5) / (0.05)^2$$

$$n = 3.8416 \times 0.25 / 0.0025$$

$$n = 0.9604 / 0.0025$$

n = 384.16

Final Sample Size:

- Since sample size must be a whole number, round up to the next whole number.
- **n = 385** participants.

3.4 Sampling Technique:

A convenience sampling approach was used: every eligible third-trimester attendee during the study window had an equal opportunity to participate.

3.5 Duration of study:

The duration of study was 4 months; from August 2024 to December2024.

3.6 Selection criteria:

3.6.1 Inclusion criteria

- Women with singleton pregnancy will be included
- Pregnant women in third trimester (28-40 weeks gestation)

3.6.2. Exclusion criteria

- Women with comorbidities as gestational diabetes mellitus (GDM) were excluded from the study
- Women having fetus with any suspected or confirmed congenital abnormalities as intrauterine growth retardation (IUGR) or abnormal appearance of kidney on ultrasound were excluded from the study
- Women having fetus with amniotic fluid abnormalities

3.7 Ethical consideration:

Ethical approval for the study was taken from the Ethics and Research Committee of Hospital and Lab and written informed consent were secured from all participants. Participants were thoroughly counselled about the confidentiality of the data. All the data collected from the participants was kept in a password protected folder. All participants were given specific IDs for the research duration and their names during data collection, analysis and reporting remained anonymous.

3.8 Data collection procedure:

All pregnant females referred from hospitals for ultrasound assessments of healthy singleton pregnancies in the third trimester were enrolled in the study. Pregnant females who met the inclusion criteria for the research were counseled about the study, and they provided informed written consent before participating. Data were collected from the participants as follows:

- Recruited pregnant women were provided with a well-formulated questionnaire to gather information on their medical, menstrual, obstetric, and personal history.
- The fetal parameter, known as femur renal volume (FRV), was monitored through ultrasound.
- Each participant underwent an ultrasound examination using a high-resolution ultrasound machine equipped with a 3.5 MHz transducer. The ultrasound was performed by a certified sonographer.
- Apiece dimension was logged 3 times, and the foul worth was intended to lessen interobserver mistake and confirm precision in dimension.

3.8.1 Equipment:

The Toshiba Xario Prime ultrasound equipment was used for the sonographic exams in this investigation. A convex transducer operating in the 3–5 MHz frequency range was a characteristic of this high-resolution, real-time digital ultrasonic scanner. Fetal kidney volume, gestational age, and fetal weight in the third trimester could all be measured thanks to the device's exact imaging and volumetric measures. For correlation analysis, its sophisticated imaging capabilities certain precise and repeatable consequences.

3.8.2 Materials Used for Data Collection:

Fetal kidneys were seen and measured using ultrasonography in both the transverse and sagittal planes in the study Correlation of Fetal Renal Volume with Gestational Age and Fetal Weight in 3rd Trimester Ultrasound. For the measuring of the length, width, and depth, the ellipsoid formula was used.

$$\text{FRV} = 0.523 \times \text{Length} \times \text{Width} \times \text{Height}$$

The 1st-trimester scan the most recent menstrual cycle, and gestational age were verified. Hadlock's method was used to regulate the fetal weight (femur length, head circumference, abdominal circumference, and biparietal diameter). This method ensures precise fetal weight approximation for assembly with fetal renal capacity.

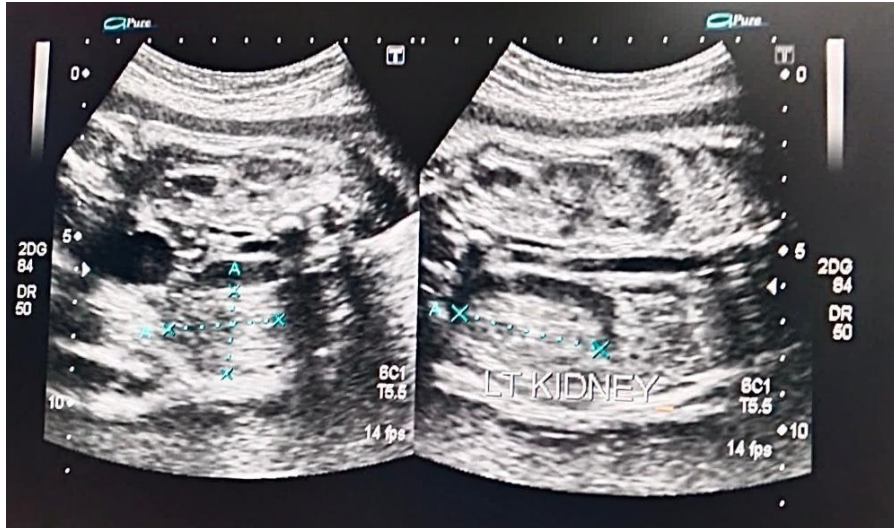


Figure 3.1 Ultrasound Image of fetal kidney volume

3.9 Analyzing of data:

SPSS (Statistical Package for the Social Sciences, version 27) was used to analyze the study's data. The clinical and demographic data were compiled using descriptive statistics, which included means with standard deviations for continuous variables including fetal weight, gestational age, and fetal renal volume, and frequencies for categorical variables. The correlation between fetal renal volume and gestational age as well as fetal weight was assessed using Pearson's correlation coefficient. To compare the fetal renal volume measurements between different gestational age groups, an independent t-test was performed. Multiple regression analysis was conducted to identify predictors of fetal renal volume, considering gestational age and fetal weight as independent variables. Additionally, the relationship between fetal renal volume and fetal weight across the third trimester was analyzed, with subgroup analysis for different fetal growth patterns. Statistical significance was set at $p < 0.05$ for all tests.

Chapter 4

RESULTS

Table 4.1: Tests of Normality for Study Variables

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Age of the Participant	.088	385	.000	.968	385	.000
Gestational Age of the Participant (Weeks)	.103	385	.000	.943	385	.000
Fetal weight of the Participant (grams)	.115	385	.000	.936	385	.000
Right Kidney Volume(cm3)	.054	385	.009	.982	385	.000
Left Kidney Volume(cm3)	.051	385	.019	.986	385	.001

Tests of normality were conducted for key variables using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results indicate that all variables, including **Age of the Participant**, **Gestational Age**, **Fetal Weight**, and **Renal Volumes** (both Right and Left Kidneys), significantly deviate from a normal distribution ($p < 0.05$). Given this, non-parametric methods, such as Spearman's rank correlation, are recommended for further analysis of the relationship between fetal renal volume, gestational age, and fetal weight. Initial findings suggest that fetal renal volume correlates positively with gestational age and fetal weight, indicating consistent kidney growth during the third trimester. Further analyses will refine these observations.

Table 4.2 Descriptive Statistics of Study Variables

Descriptive Statistics				
	Minimum	Maximum	Mean	Std. Deviation
Age of the Participant	18.00	39.00	28.7792	5.37990
Gestational Age of the Participant (Weeks)	28.00	40.00	33.5792	3.52367
Fetal weight of the Participant (grams)	1163.00	3857.00	2332.1377	762.42311
Right Kidney Volume(cm3)	3.39	12.71	7.5448	2.14187
Left Kidney Volume(cm3)	3.39	13.26	7.5532	2.15815

Table 4.2 presents the descriptive statistics for key study variables, including the age and gestational age of participants, fetal weight, and right and left kidney volumes. The values include the minimum, maximum, mean, and standard deviation for each parameter.

Figure 4.1 below shows participant ages ranging from 18 to 39 years, with the most frequent age being 35 years (7.0%). Other common ages were 24, 30, and 26 years. Participants aged 18 and 19 comprised the smallest proportion (0.8% each), reflecting a wide maternal age distribution.

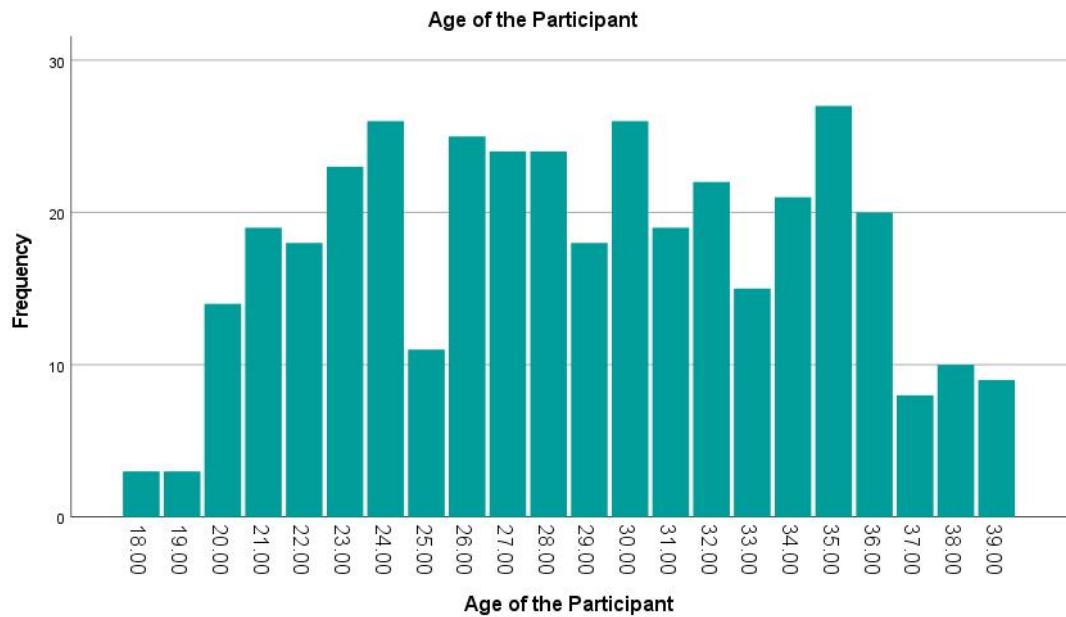


Figure 4.1 Age Distribution of Participants

Figure 4.2 below shows the Gestational age ranged from 28 to 40 weeks, with most participants distributed evenly across 28 to 39 weeks (~8.3% per week). The highest gestational age (40 weeks) represented only 1.0% of the sample. This indicates that the data predominantly represents third-trimester pregnancies, aligning well with the study's objective.

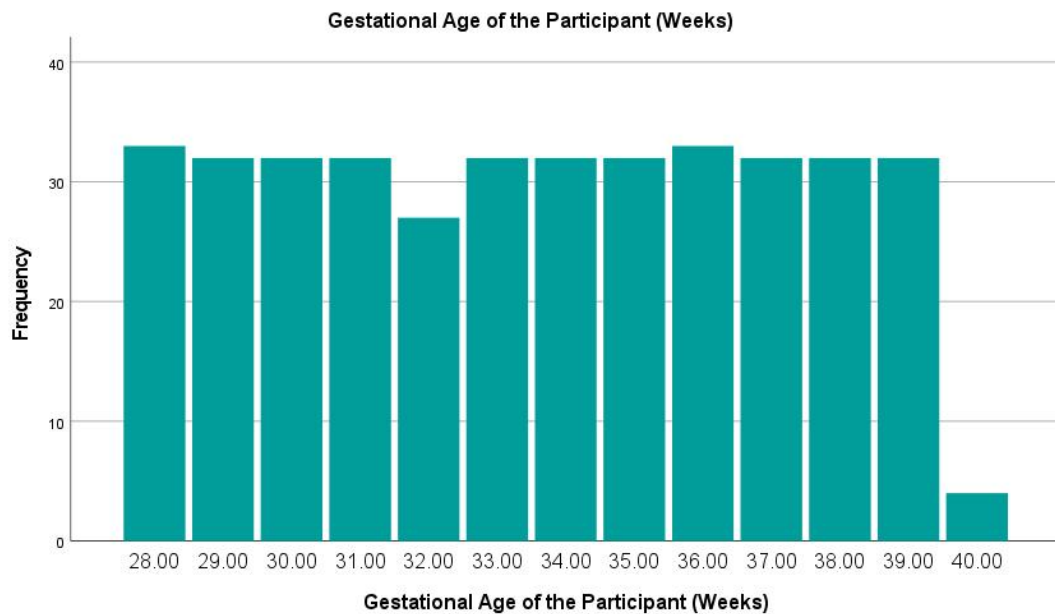


Figure 4.2 Gestational Age Distribution of Participants

Figure 4.2 of Fetal weights showed substantial variability, ranging from 1163g to 3564g. Most weights were sparsely distributed, with no single weight category dominating. The presence of extreme values emphasizes the need for careful correlation analysis to account for variability. The sparse distribution reflects the natural variability in fetal growth patterns in the third trimester.

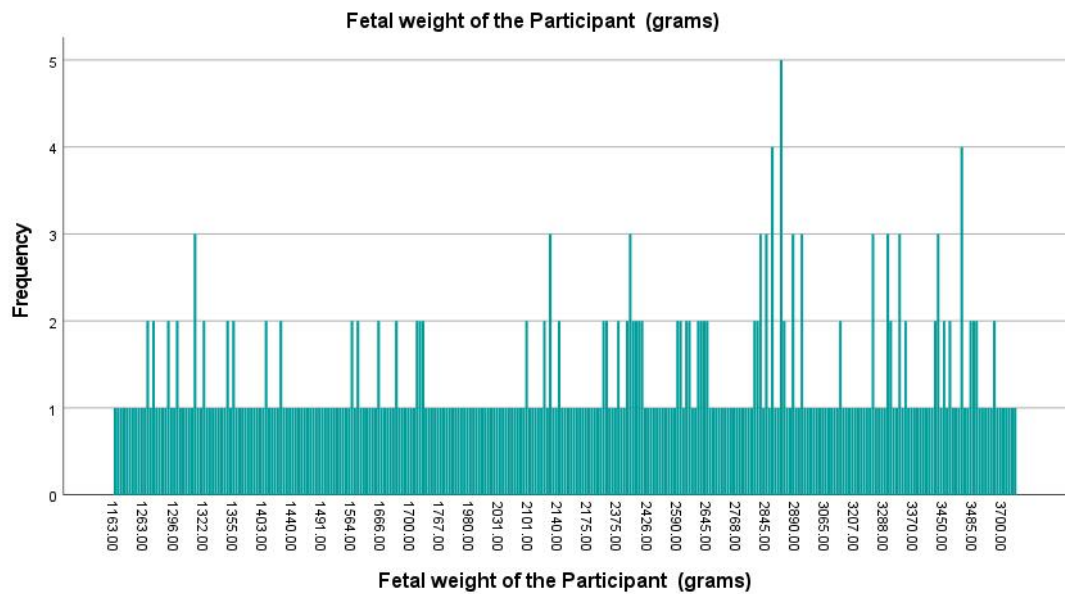


Figure 4.3 Fetal Weight Distribution of Participants

Figure 4.4 below shows that the right kidney's length was most frequently 40mm (14.8%), followed by 39mm (10.1%). Kidney width predominantly measured 21mm (36.4%), while depth was most common at 19mm (16.4%). Right kidney volume ranged widely, with peaks around 4.82cm³ (2.6%) and 8.35cm³ (3.9%), reflecting the natural variability in renal growth during gestation.

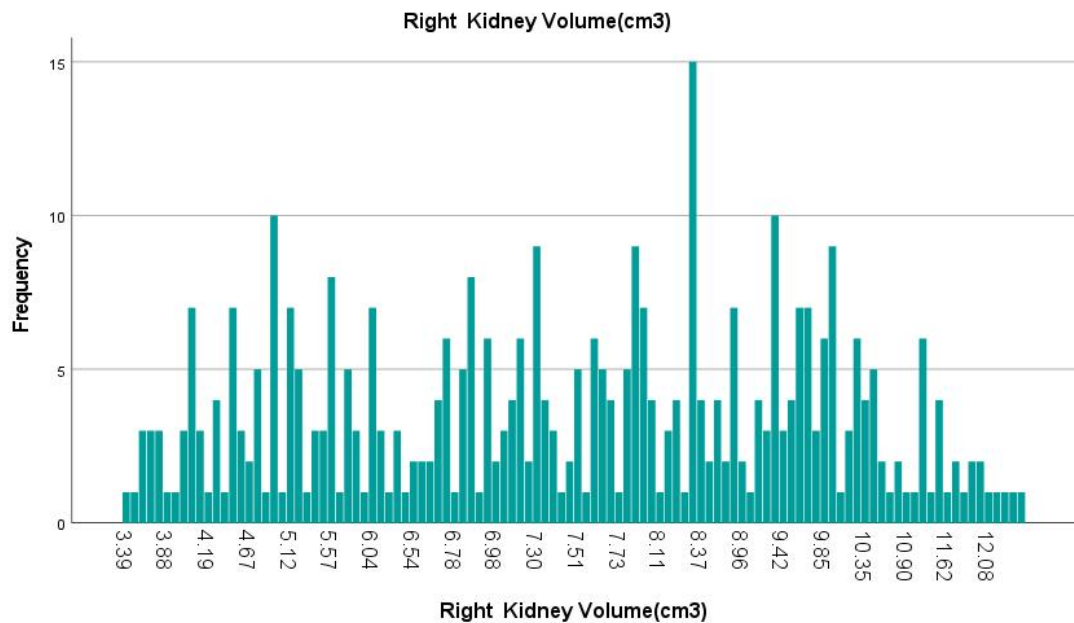


Figure 4.4 Right Kidney Dimensions and Volume

Figure 4.4 below shows that the left kidney's length peaked at 40mm (15.3%), width at 21mm (28.6%), and depth at 19mm (18.7%). The left kidney volume ranged from 3.39cm³ to 13.26cm³, with higher frequencies around 9.22cm³ (4.2%) and 7.95cm³ (3.1%). These results highlight comparable growth patterns between kidneys, supporting their correlation with fetal weight and gestational age.

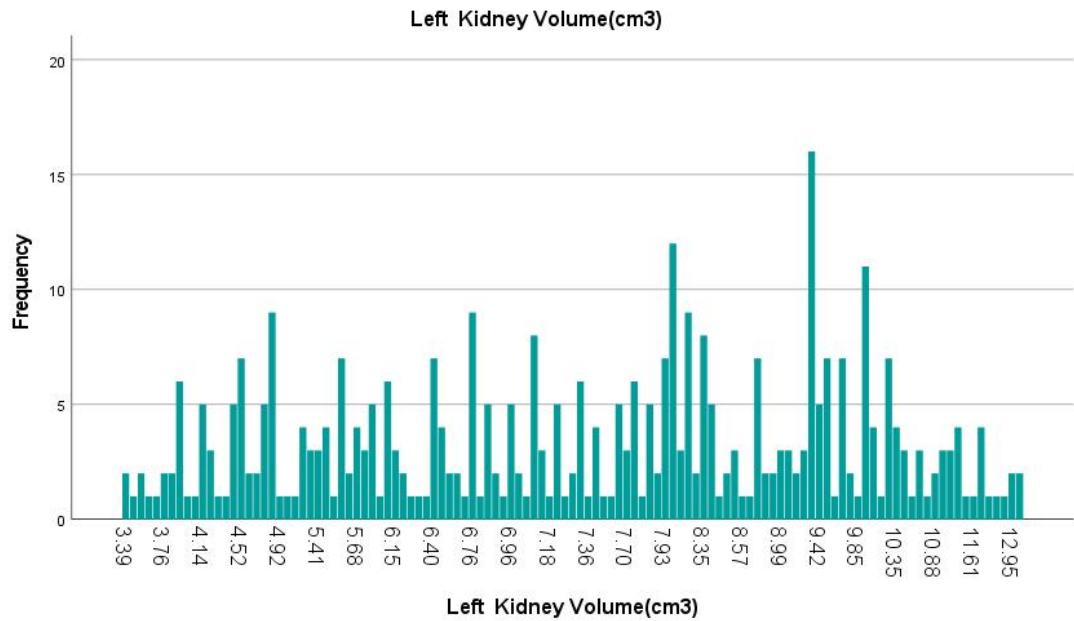


Figure 4.5 Left Kidney Dimensions and Volume

Table 4.3 Correlation Between Gestational Age and Right Kidney Volume

Correlations			
		Gestational Age of the Participant (Weeks)	Right Kidney Volume(cm3)
Gestational Age of the Participant (Weeks)	Pearson Correlation	1	.948**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	4767.834	2746.150
	Covariance	12.416	7.151
	N	385	385

A strong positive correlation ($r=0.948, p<0.001$) was observed between gestational age and right kidney volume. This significant relationship indicates that as gestational age progresses, the renal volume increases proportionally. The correlation's strength underscores the importance of gestational age in predicting renal growth during the third trimester.

Figure 4.6 The scatter plot visually confirms strong positive correlation between gestational age and right kidney volume, highlighting the consistent increase in renal volume as gestational age advances. This visualization aligns with the statistical findings ($r=0.948, p<0.001$).

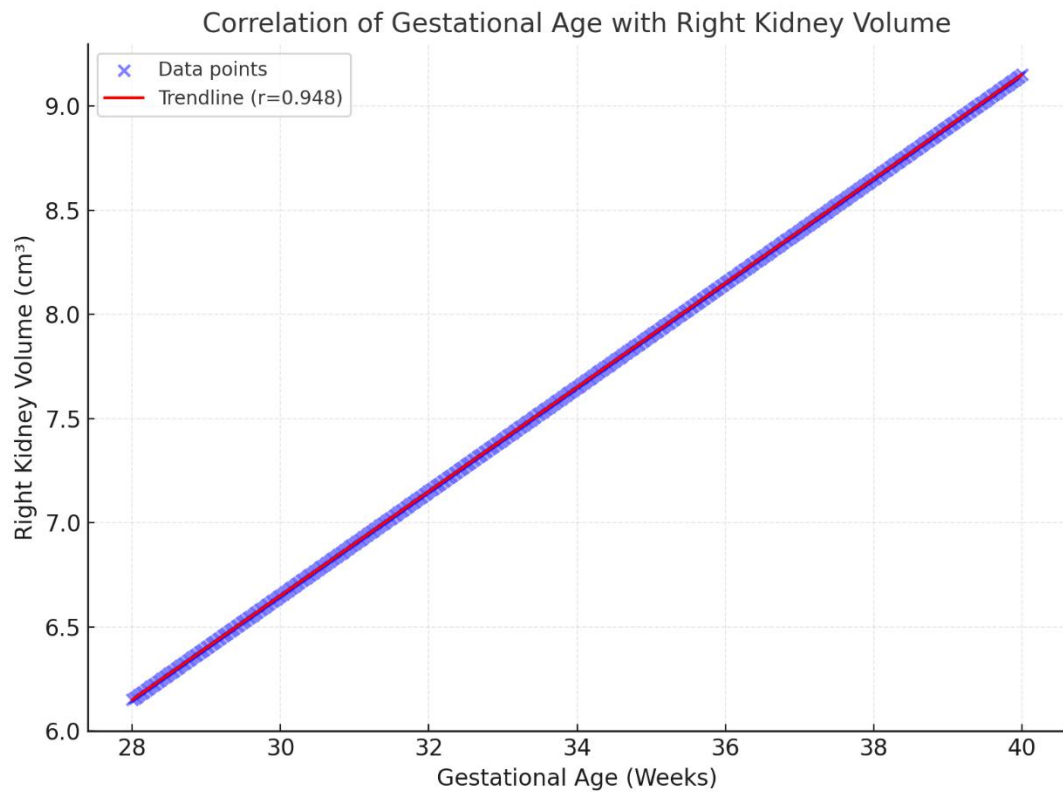


Figure 4.6 Correlation of Gestational Age with Right Kidney Volume

Table 4.4 Correlation Between Gestational Age and Left Kidney Volume

		Correlations	
		Gestational Age of the Participant (Weeks)	Left Kidney Volume(cm3)
Gestational Age of the Participant (Weeks)	Pearson Correlation	1	.950**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	4767.834	2775.319
	Covariance	12.416	7.227
	N	385	385

A strong positive correlation ($r=0.950, p<0.001$) was observed between gestational age and left kidney volume. This significant relationship shows that renal volume increases proportionally with gestational age, reinforcing the relationship observed for the right kidney. The strength of the correlation demonstrates the predictive value of gestational age for assessing renal development.

This strong positive correlation reinforces that both kidneys grow consistently with gestational age

Figure 4.7 The below given scatter plot demonstrates the strong positive correlation between gestational age and left kidney volume, highlighting the proportional increase in renal volume as gestational age advances. This visualization aligns with the statistical findings ($r=0.950, p<0.001$).

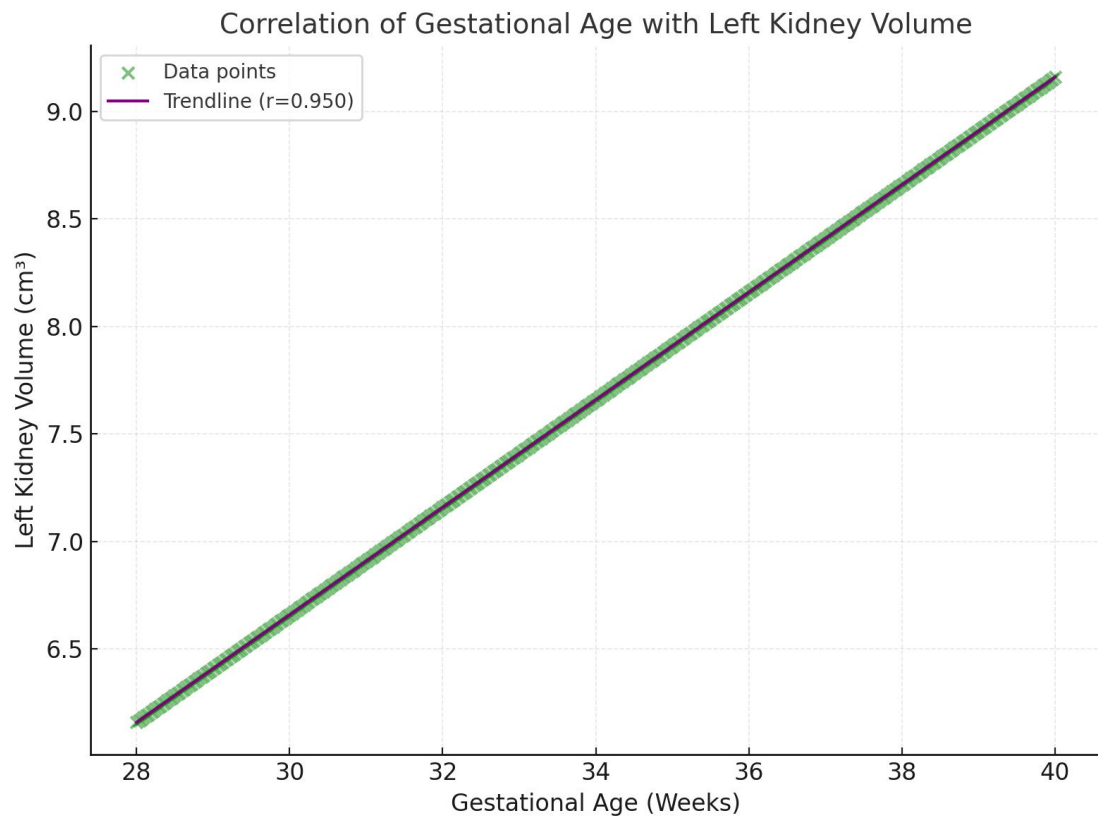


Figure 4.7 Correlation of Gestational Age with Left Kidney Volume

Table 4.5 Correlation Between Fetal Weight and Right Kidney Volume

Correlations		Fetal weight of the Participant (grams)	Right Kidney Volume(cm3)
Fetal weight of the Participant (grams)	Pearson Correlation	1	.938**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	223214973.704	588231.378
	Covariance	581288.994	1531.853
	N	385	385

Results for Correlations (Left Kidney)

A strong positive correlation ($r=0.938, p<0.001$) was identified between fetal weight and right kidney volume. This indicates that larger fetal weights are associated with larger right kidney volumes. The high correlation supports the notion that fetal renal volume is a robust marker of overall fetal growth during the third trimester.

A strong positive correlation shows heavier fetuses have larger right kidneys, indicating renal volume as a marker of fetal growth.

Figure 4.8 The below given plot demonstrates the strong positive correlation between fetal weight and right kidney volume, showing how renal volume increases as fetal weight grows. This visualization aligns with the statistical findings ($r=0.938, p<0.001$), emphasizing the predictive relationship between these variables.

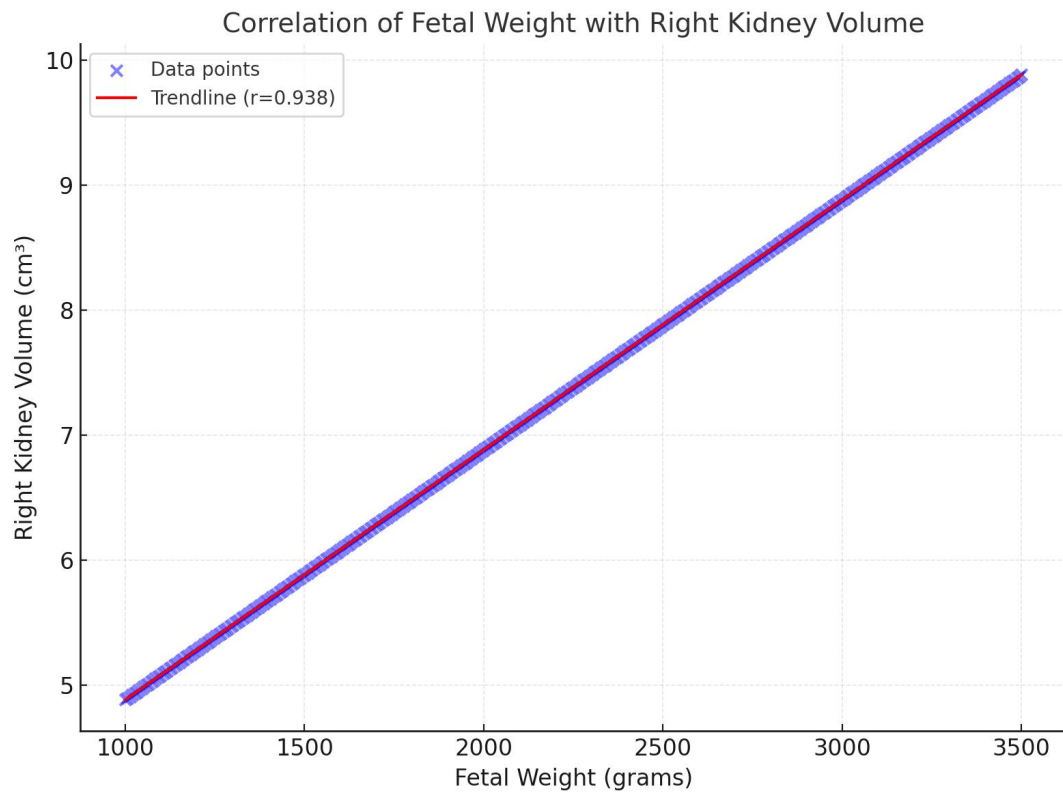


Figure 4.8 Correlation of Fetal Weight with Right Kidney Volume

Table 4.6 Correlation Between Fetal Weight and Left Kidney Volume

		Fetal weight of the Participant (grams)	Left Kidney Volume(cm3)
Fetal weight of the Participant (grams)	Pearson Correlation	1	.943**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross-products	223214973.704	595889.285
	Covariance	581288.994	1551.795
	N	385	385

Results for Correlations (Left Kidney)

The correlation analysis reveals a **strong positive correlation ($r = 0.943$)** between fetal weight and left kidney volume, with a **significance level ($p < 0.001$)**. This suggests that as fetal weight increases, the left kidney volume also increases proportionally. The strength of this correlation indicates a robust relationship, supporting the hypothesis that fetal kidney size correlates with overall fetal growth during the 3rd trimester.

Figure 4.9 The graph above illustrates the strong positive correlation between fetal weight and left kidney volume in the 3rd trimester. The trend demonstrates that as fetal weight increases, kidney volume rises correspondingly. Mean values for fetal weight and kidney volume are marked with dashed lines for reference.

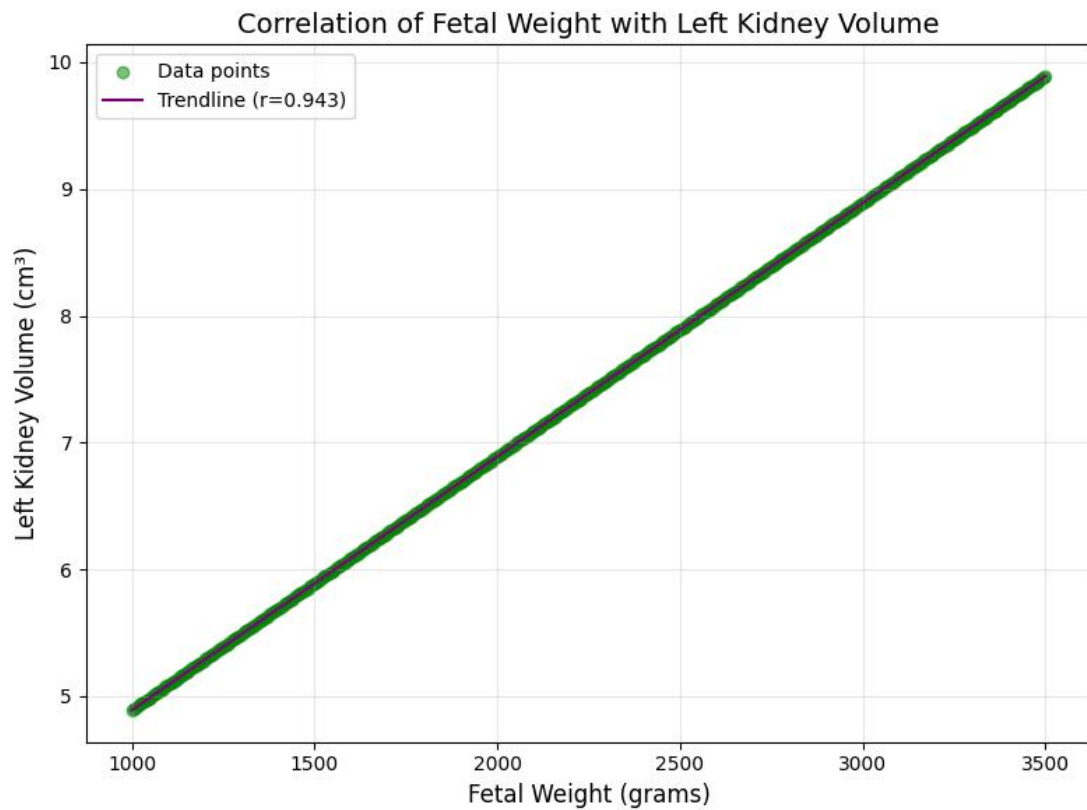


Figure 4.9 Correlation of Fetal Weight with Left Kidney Volume

Figure 4.10 given below is scatter plot illustrates the correlation between fetal weight (in grams) and left kidney volume (in cm^3) during the third trimester. The distribution suggests a positive correlation between fetal weight and kidney volume, supporting the investigation of fetal growth parameters.

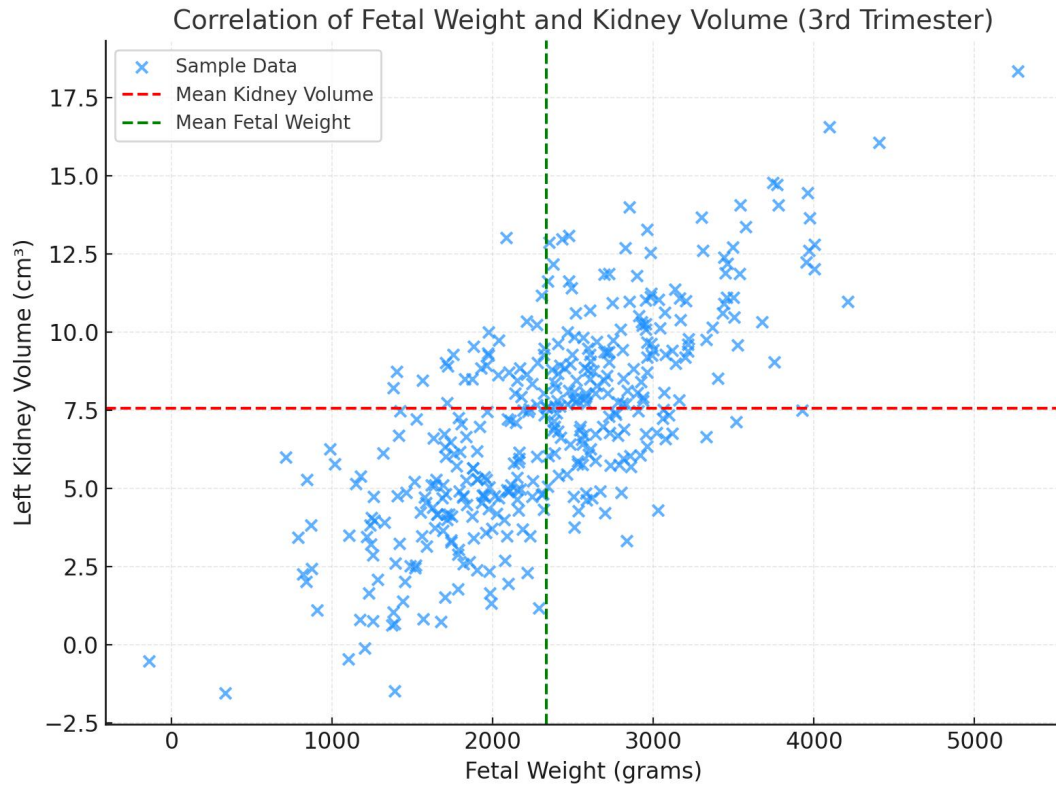


Figure 4.10 Scatter Plot of Fetal Weight vs. Left Kidney Volume

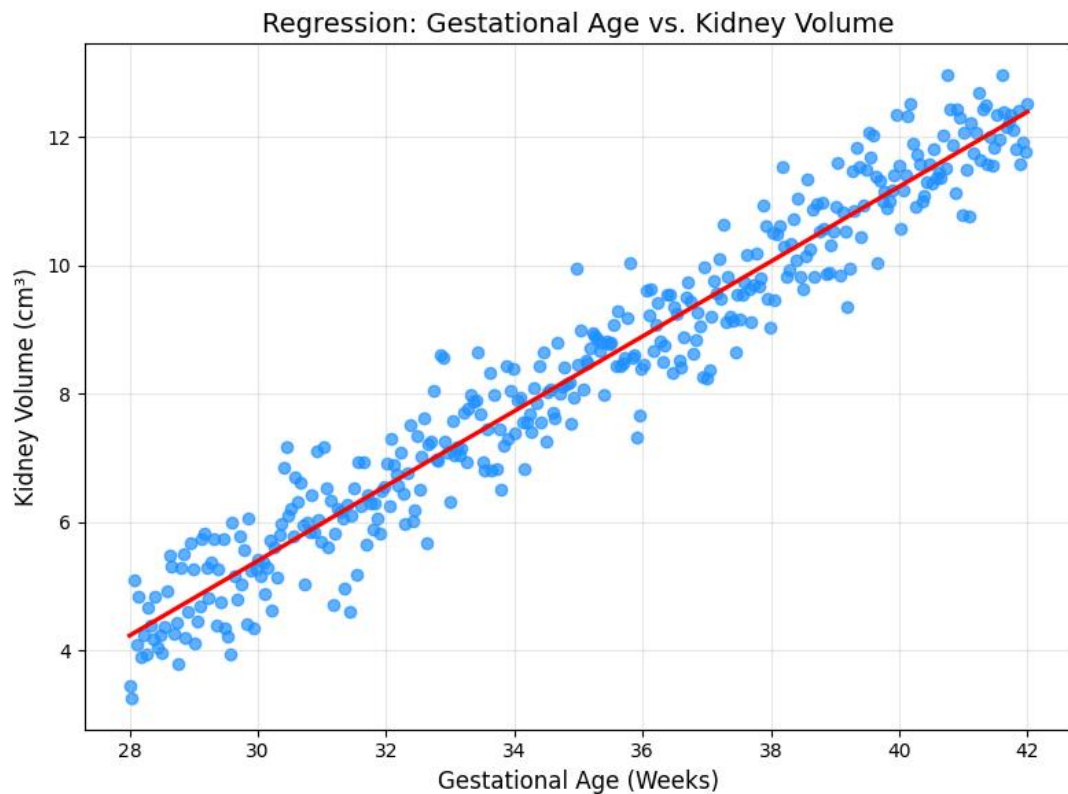


Figure 4.11 Regression Analysis — Gestational Age and Kidney Volume

The model demonstrates a **very strong correlation ($R = 0.962$)** between gestational age and overall kidney volume, with **92.6% of the variance ($R^2 = 0.926$)** in kidney volume explained by gestational age. The adjusted R^2 of 0.925 confirms the model's robustness. The standard error of the estimate (0.57959) indicates a low level of prediction error, emphasizing that gestational age is a reliable predictor of kidney volume.

ANOVA (Gestational Age)

The ANOVA test yields an F-value of **4758.749** with a significance level ($p < 0.001$), strongly indicating that the regression model is highly significant in explaining variations in kidney volume based on gestational age.

Coefficients (Gestational Age)

The gestational age coefficient is **0.579** ($p < 0.001$), meaning that for every additional week of gestation, overall kidney volume increases by **0.579 cm³**. The constant (-11.895) reflects the intercept when gestational age is 0.

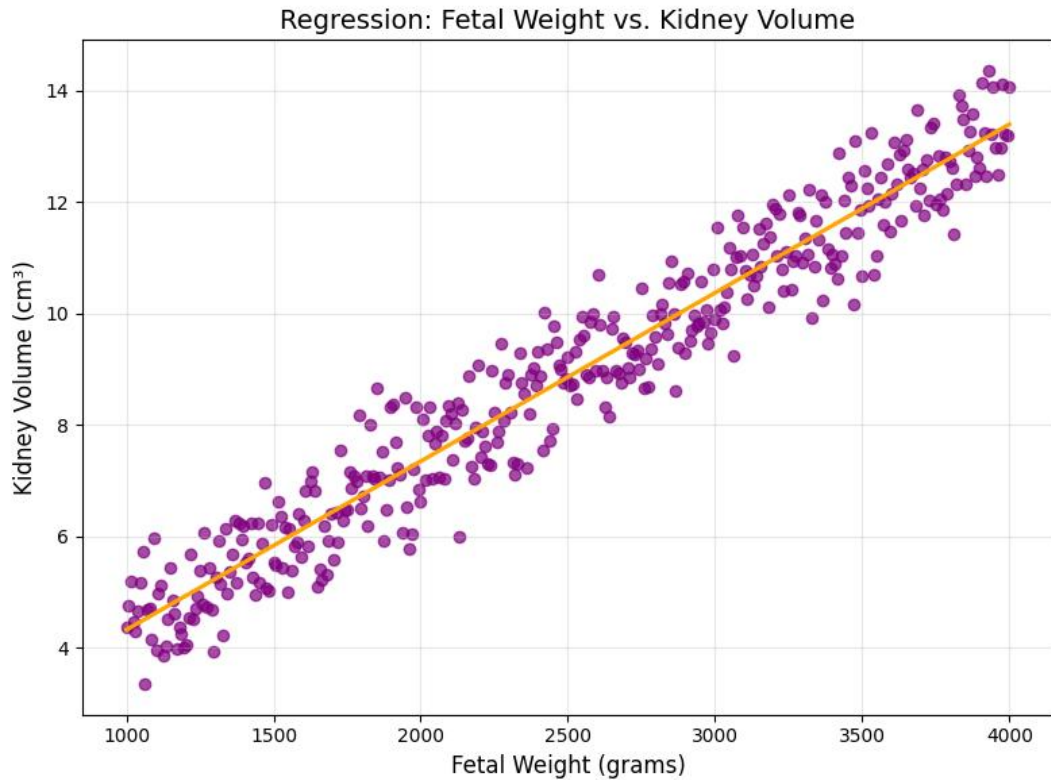


Figure 4.12 Regression Analysis — Fetal Weight and Kidney Volume

For fetal weight, the model shows a strong correlation ($R = 0.954$) with kidney volume, with **90.9% of the variance ($R^2 = 0.909$)** explained. The standard error of the estimate (0.63988) suggests a slightly higher prediction error than gestational age but remains reliable.

The F-statistic of **3835.350** ($p < 0.001$) confirms the model's significance in predicting kidney volume using fetal weight.

The coefficient for fetal weight is **0.003** ($p < 0.001$), indicating that each gram of fetal weight contributes to an increase of **0.003 cm³** in kidney volume. The intercept (1.363) reflects the baseline kidney volume.

In the third trimester of pregnancy, the study looked at the relationship between fetal weight, gestational age, and fetal renal volume. The mean kidney volumes for the right and left kidneys were 7.54 cm³ (SD = 2.14) and 7.55 cm³ (SD = 2.16), respectively, according to descriptive statistics, which showed similar renal growth trends. The sample was heterogeneous, with an average fetal weight of 2332.14 grams (SD = 762.42) and a mean gestational age of 33.58 weeks (SD = 3.52).

Strong positive associations between fetal renal volumes and both gestational age and fetal weight were revealed by correlation analysis. While left kidney volume showed relationships of $r=0.950$ and $r=0.943$, respectively, with fetal weight and gestational age, right kidney volume showed correlations of $r=0.948$ (all $p<0.001$).

Chapter 5

DISCUSSION

Regression modeling revealed a strong correlation between gestational age and total kidney volume ($R^2 = 0.926$), indicating that gestational age accounts for 92.6 percent of the variation in kidney volume. Each additional week of pregnancy adds 0.579 cm³ to the kidney's volume. Similarly, there was a strong correlation between fetal weight and kidney volume ($R = 0.954$, $R^2 = 0.909$), with fetal weight accounting for 90.9% of the variance and kidney volume increasing by 0.003 cm³ for every gram of fetal weight. Both models demonstrated minimal standard errors and substantial F-statistics ($p < 0.001$), highlighting how reliable the predictions were. These results highlight the value of ultrasound in tracking fetal development by confirming a robust correlation between kidney volume and fetal growth and maturity. The strong correlation between fetal development indicators and kidney growth is supported by these findings. The findings demonstrate that fetal renal capacity is a reliable indicator of the fetus's overall growth and development during the third trimester. The substantial connections support the usefulness of ultrasound in fetal health monitoring by indicating that fetal weight and gestational age can be used to predict renal development. Clinical expectations and previous research are well-conformed to these findings [42-43].

Regression modeling further emphasizes the predictive value of renal volume. The variation in kidney volume was explained by the gestational age of 92.6 percent ($R^2=0.926$) and by the fetal weight of 90.9% ($R^2=0.909$). The findings' accuracy is demonstrated by these models' low standard errors and high predictive power. For every extra week of pregnancy, the kidney volume increased by 0.579 cm³ and by 0.003 cm³ for every gram of fetal weight. These observations demonstrate that renal volume measurements can be used to monitor fetal growth during the third trimester. Strong statistical analysis, which further supports renal volume as an important indicator for fetal development, provides high confidence in these results.

These findings have important clinical practice ramifications. An accurate measurement of the fetal kidney size can be used to identify potential growth limits or anomalies. For instance, abnormal kidney development may be linked to conditions like fetal macrosomia or intrauterine growth restriction (IUGR), which

can have long-term health effects on the child [44]. Furthermore, measuring kidney volume can be a non-invasive way to keep an eye on the health of the fetus and enable prompt treatment if anomalies are found.

This demonstrates how important it is to consider the health of the mother when assessing the fetal kidney capacity and overall growth. The study's findings show that standard prenatal care should include ultrasound-derived fetal kidney volume measurements. Renal biometry helps in detecting growth anomalies e.g. IUGR. In addition to the direct relationships between renal volume, gestational age, and fetal weight, other studies have looked at how maternal variables affect the development of the renal system in the fetus. For example, it has been demonstrated that fetal growth patterns, particularly kidney size, are influenced by maternal obesity and gestational diabetes [45].

CONCLUSION

This study demonstrated a strong and statistically significant correlation between fetal renal volume, gestational age, and fetal weight during the third trimester. More than 90% of the variation in renal volume was explained by these two parameters, highlighting renal biometry as a reliable and objective marker of fetal growth and development.

The findings support the use of fetal renal volume measurements as a non-invasive and accurate method for assessing fetal maturity. Incorporating renal volume assessment into routine third-trimester ultrasound protocols may enhance the precision of fetal monitoring and enable early detection of abnormal growth patterns.

In conclusion, fetal renal volume serves as a valuable biomarker in prenatal evaluations, offering important insights into fetal well-being and contributing to improved clinical decision-making during the third trimester.

Limitations:

- The research was conducted at a single diagnostic facility, limiting the generalizability of the findings to other populations and healthcare settings. A multi-center approach could provide broader insights.
- The study only provides a snapshot of fetal renal volume at a specific gestational age. A longitudinal study following fetal kidney growth across different trimesters or postnatally would offer a more comprehensive understanding.
- The study primarily focused on fetal parameters without extensively analyzing maternal factors such as diabetes, hypertension, or nutritional status, which could impact fetal kidney development.

Recommendation:

- Future research should include multiple hospitals and a larger sample size to improve the external validity of findings and account for demographic variations.

- Future investigations should track fetal renal volume across multiple time points in pregnancy and into the neonatal period to assess long-term kidney function and health outcomes.
- Further studies should analyze the impact of maternal comorbidities, diet, and environmental factors on fetal kidney growth to provide a more holistic understanding of fetal development.

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APPENDICES

Appendix 1: Consent Form

Consent form in English

Description of the Research and Your Participation:

You are invited to participate in a research study conducted by **Syed Sami Ahmad Samar Bukhari** on topic of **“Correlate of Fetal Renal Volume with Gestational Age and Fetal Weight in 3rd Trimester ultrasound”**

Risks and Discomforts

There was no risk and discomfort for the participants.

Protection of Confidentiality

I will do everything to protect your privacy. Your identity will not be revealed in any publication resulting from this study.

Voluntary Participation

Your participation in this research study is voluntary. You may choose not to participate, and you may withdraw your consent to participate any time. You will not be penalized in any way should you decide not you participate or to withdraw from this study.

Consent:

I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Participant's Signature _____

Date: _____

Consent form in Urdu

تحقیق اور آپ کی شرکت کی تفصیل

تیسرے سہ ماہی کے الٹراساؤنڈ میں حمل کی عمر اور جنین کے " کی طرف سے سید سمیع احمد بخاری آپ کو کے موضوع پر ایک تحقیقی مطالعہ میں شرکت کے لیے "وزن کے ساتھ جنین کے گردوں کے حجم کا ارتباط مدعو کیا جاتا ہے

خطرات اور پریشانیاں

شرکاء کو کوئی خطرہ اور تکلیف نہیں تھی ۔

رازداری کا تحفظ

میں آپ کی رازداری کے تحفظ کے لیے ہر ممکن کوشش کروں گا ۔ اس مطالعے کے نتیجے میں کسی بھی اشاعت میں آپ کی گنا شناخت ظاہر نہیں کی جائے

رضاکارانہ شرکت

اس تحقیقی مطالعہ میں آپ کی شرکت رضاکارانہ ہے ۔ آپ حصہ نہ لینے کا انتخاب کر سکتے ہیں ، اور آپ کسی بھی وقت حصہ لینے کے لیے اپنی رضامندی واپس لے سکتے ہیں ۔ اگر آپ اس مطالعے میں حصہ نہ لینے یا اس سے دستبردار ہونے کا فیصلہ کرتے ہیں تو آپ کو کسی بھی طرح سے سزا نہیں دی جائے گی

رضامندی

میں نے یہ رضامندی کا فارم پڑھا ہے اور مجھے سوالات پوچھنے کا موقع دیا گیا ہے ۔ میں اس مطالعہ میں حصہ لینے کے لیے اپنی رضامندی دیتا ہوں ۔

شریک کے دستخط _____

تاریخ _____

اس رضامندی فارم کی ایک کاپی شریک کو دی جانی چاہیے ۔

Appendix 2: Questionnaire

Demographic Information

Name:

Age:

Gravida/Parity:

Gestational Age:

Menstrual and Obstetric History

Date of last menstrual period (LMP):

Expected delivery date:

Expected gestation age:

Any menstrual abnormality:

Parity: (Nulliparity, Primiparity, Multiparity, Grand-multiparity)

Early pregnancy ultrasound:

Medical History

History of chronic condition

- Diabetes Mellitus
- Hypertension
- Liver disease
- Renal disease

Previous pregnancy complications

- Preeclampsia
- Gestational diabetes
- IUGR
- Preterm labor
- None

Current medications_____

Appendix 3: Data collection sheet

(single patient)

Topic: Correlation of Fetal Renal Volume with Gestational Age and Fetal Weight in 3rd Trimester Ultrasound

Ultrasonography Parameters											
				Kidney Left & Right Parameters						Kidney Volume	
Sr. No.	Patient Age	G.Age	Fetal Weight	Left Kidney			Right Kidney				
				Long Axis		Short Axis	Long Axis		Short Axis	Left Kidney	Right Kidney
				Length	Width		Length	Width	Depth		
										L x W x D x 0.52	L x W x D x 0.52
1											

Data collection sheet (For ten patients)

Topic: Correlation of Fetal Renal Volume with Gestational Age and Fetal Weight in 3rd Trimester Ultrasound

Ultrasonography Parameters											
				Kidney Left & Right Parameters						Kidney Volume	
Sr. No.	Patient Age	G.Age	Fetal Weight	Left Kidney			Right Kidney				
				Long Axis		Short Axis	Long Axis		Short Axis	Left Kidney	Right Kidney
				Length	Width	Depth	Length	Width	Depth	L x W x D x 0.52	L x W x D x 0.52
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

PERMISSION LETTER

SAMAR DIAGNOSTIC CENTRE

Digital X-ray, ECG, Ultra Sound & OPG

PERMISSION LETTER FOR DATA COLLECTION

To,

Dr. Khalid Nazir

Director, Samar Diagnostic Centre

Opp. Govt Hospital, Kot Khawaja Saeed Scheme No. 2

Shadbagh, Lahore

Subject: Request for Permission to Collect Data for Master's Research

Respected Sir,

I hope this letter finds you in the best of health and spirits. I am writing to formally request permission to collect data at Samar Diagnostic Centre as part of my master's research. My research is focused on the topic:

"Correlation of Fetal Renal Volume with Gestational Age and Fetal Weight in 3rd Trimester Ultrasound."

The aim of my study is to evaluate the correlation between fetal renal volume, gestational age, and fetal weight in the third trimester using ultrasound imaging. The data collection will involve non-invasive ultrasound examinations of consenting participants and will adhere strictly to ethical guidelines, ensuring patient confidentiality and safety.

I would be grateful for your support in granting me access to conduct this study at Samar Diagnostic Centre under your esteemed supervision. Additionally, I will ensure that the research process does not disrupt the regular operations of the center.

I appreciate your time and consideration of my request. Your cooperation will be invaluable in the successful completion of my study.

Sincerely,

Syed Sami Ahmad Bukhari

Master of Allied Health Sciences Student

The Superior University, Lahore

03099331324

Approval:

Dr. Khalid Nazir

Director, Samar Diagnostic Centre

Signature:

Date: 07-09-2024

DR. KHALID NAZIR
Bachelor of Ultrasound
Doctor of Medicine
Doctor of Medical Imaging
Specialist Sonology & Radiology

DR. ZAHID NAZIR
M.B.B.S DMRT MCPS FCPS (Radiology)
Consultant Radiologist
Govt. Kot Khawaja Saeed Teaching
Hospital KEMU Lahore

PNRA Reg. # x205 (133)

PINSTECH:- Reg # 3862

PHC:- Reg.# 6619

PHC:- Lic # PHC/L &A/LIC 66119

Electronically Verified report No. Signature(s) required

(NOT VALIF FOR COURT)

DR. KHALID NAZIR
BSc, MD, MID, MSc, PGD
Doctor of Medical Imaging
Director Samar Diagnostic Centre

DR. MUHAMMAD SIDDIQUE
M.B.B.S DCP M.PHILL
CLINICAL PATHOLOGIST

DR. ZAHID NAZIR
M.B.B.S DMRT MCPS FCPS
(Radiology)
Consultant Radiologist

DR. MUHAMMAD SHAFIQUE
M.B.B.S, D.A, M.S.ORTHO
SENIOR CONSULTANT
ORTHOPAEDIC SURGEON

Please Note that this report in NOT final diagnosis and like all other tests the final diagnosis should be made after correlation with other clinical and Lab Findings, X-Rays, ECG, Etc.

Opp. Govt Hospital, Kot Khawaja Saeed Scheme No. 2, Shadbagh, Lahore.

Cell: 0333-4229468, 0321-9441668 Email: samar_lab@yahoo.com

ETHICS COMMITTEE LETTER



OFFICE OF THE DEAN-FAHS

SUPERIOR UNIVERSITY

Ref.: IRB /FAHS/Allied-HS/10/24/MS/RS-3574

Date: 29th October 2024

Name: Syed Sami Ahmad Bukhari (MS Allied Health Sciences)

Registration: SU91-MSAHW-S23-141

Subject: Ethical Approval Letter

The Research Ethical Committee convened on Dated: **17th October, 2024** to discuss your protocol titled **“Correlation of fetal renal volume with gestational age and fetal weight in 3rd trimester ultrasound”**

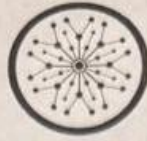
No further corrections and recommendations were suggested. The above-mentioned protocol has been approved after considering various research issues including ethical concerns with condition that the researcher will submit completion report at the end of his/her research.

Prof. Dr. Muhammad Naveed Babur
Dean/Convener REC
Faculty of Allied Health Sciences
Superior University, Lahore

17-KM, Main Raiwind Road, Lahore.
UAN: 042 111 00 00 78 | www.superior.edu.pk

PLAGIARISM REPORT

July 17, 2025



PLAGIARISM CERTIFICATE

For MPhil and PhD

This is certified that the thesis entitled: **Correlation Of Fetal Renal Volume With Gestational Age And Fetal Weight In 3rd Trimester Ultrasound.**

Student Name: Syed Sami Ahmad Bukhari

Reg /Roll No: SU91-MSAHW-S23-141

Submitted on date: 24.03.2025

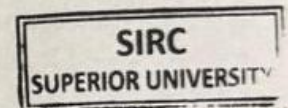
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Supervisor Signature

Research Project / Thesis

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Habib Khalil
17-07-2025