Original Article

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

Syed Sami Ahmad Bukhari,[1] Hafiz Ayaz Ahmad,[2] Amna Noor,[3] Khalid Nazir,[4] Sibghatullah,[5] Aroosa Manazir[6]

Abstract

Objective:.To investigate the correlation between fetal renal volume, gestational age, and fetal weight in the third trimester to establish renal volume as a reliable marker for prenatal monitoring.
Study design: It was a Cross-Sectional study.
Place and duration of study: The study was conducted at Samar Diagnostic Lab, Lahore, from July to December 2024.
Material and Methods: This study included 385 third-trimester pregnancies. Ultrasonographic measurements of fetal renal volume were performed for both kidneys. Descriptive statistics and tests of normality were applied to analyze growth patterns. Correlation analyses (Pearson and Spearman) evaluated relationships between renal volume, gestational age, and fetal weight, while regression models quantified predictive contributions of these parameters to renal volume.
Results: Mean renal volumes for the right and left kidneys were 7.54 cm³ (SD = 2.14) and 7.55 cm³ (SD = 2.16), respectively. Gestational age (mean = 33.58 weeks) and fetal weight (mean = 2332.14 grams) exhibited strong correlations with renal volume ($r > 0.94$, $p < 0.001$). Regression analysis revealed that gestational age and fetal weight explained 92.6% ($R^2=0.926$) and 90.9% ($R^2=0.909$) of the variance in renal volume, respectively. Each additional week of gestation contributed 0.579 cm³ to renal volume, while each gram of fetal weight added 0.003 cm³.

Keywords: Fetal renal volume, gestational age, fetal weight, ultrasonography, third trimester, fetal growth, prenatal assessment.

1. Introduction

Fetal renal volume is an essential parameter in monitoring fetal growth and development during the third trimester. The evaluation of renal volume provides non-invasive insights into fetal health, aiding in the detection of growth abnormalities such as intrauterine growth restriction (IUGR). The third trimester represents a crucial phase of rapid physiological growth, making it an ideal period for assessing renal development in relation to gestational age and fetal weight.[(1)]

Ultrasonography is a well-established imaging modality for assessing fetal development, offering accurate renal volume measurements and serving as a reliable predictor of fetal maturity. However, the correlation between fetal renal volume, gestational age, and fetal weight has not been fully integrated into routine prenatal care. This study aims to explore these relationships comprehensively, utilizing advanced statistical analyses and regression modeling to validate renal biometry as a critical tool for prenatal monitoring.[(2)]

The assessment of fetal renal volume through ultrasound has become an essential component of prenatal care, particularly in the third trimester. This period is critical for fetal development, and understanding the correlation between fetal renal volume, gestational age, and fetal weight can provide valuable insights into fetal health and development. The kidneys play a vital role in the production of amniotic fluid and the regulation of fluid balance, making their evaluation crucial in the context of fetal growth and potential complications such as intrauterine growth restriction (IUGR).[(3)]

Ultrasound technology has advanced significantly, allowing for more precise measurements of fetal organs, including the kidneys.

Faculty of Allied Health Sciences, The Superior University Lahore,[1,3,4,5] Lecturer, Faculty of Allied Health Sciences, The Superior University Lahore,[2] Demonstrator, Faculty of Allied Health Sciences, The Superior University Sargodha[6]
Correspondence: Syed Sami Ahmad Bukhari, Faculty of Allied Health Sciences, The Superior University Lahore **Email:** samibukhari79@gmail.com

The ability to visualize the fetal kidneys as early as 16 weeks of gestation has enhanced the understanding of renal development and its implications for fetal health.[4]

Furthermore, the relationship between fetal renal volume and gestational age has been well-documented, indicating that as gestational age increases, so does renal volume, which can be attributed to the increase in nephron number and overall kidney size.[3,4]

The correlation between fetal renal volume and gestational age has been a focal point of numerous studies. It was demonstrated that fetal kidney length is a reliable indicator of gestational age, with significant correlations observed in their cohort. This finding aligns with the work of Bravo-Valenzuela, Nathalie Jeanne, et al.who emphasized the importance of sonographic measurements of kidney length in establishing gestational age during the late second and third trimesters.[5] These studies collectively underscore the utility of renal measurements in clinical practice, particularly in cases where the date of the last menstrual period is uncertain.[6]

Moreover, the relationship between fetal renal volume and fetal weight has been explored extensively. A study posited that renal volume can serve as a surrogate indicator for nephron count in extremely low birth weight preterm infants, suggesting that renal volume is not only a marker of growth but also of functional capacity. This perspective is supported by Suluba E et al. and Abdennadher, W., et al., who found a significant association between maternal renal volume and estimated fetal weight, [6,7] indicating that maternal physiological changes during pregnancy can directly influence fetal growth metrics.[7]

Fetal renal development is a complex process that begins early in gestation and continues throughout pregnancy. By the third trimester, the kidneys are fully formed and functional, contributing significantly to the production of amniotic fluid through fetal urine 2. Studies have shown that as gestational age increases, there is a corresponding increase in renal volume, which can be quantitatively assessed using ultrasound techniques.[8]

Research indicates a strong positive correlation between gestational age and fetal renal volume. For instance, a study demonstrated that the mean kidney length increases significantly with gestational age, with a notable difference observed when comparing measurements from 22 to 39 weeks of gestation ($p < 0.001$) 3. This finding aligns with the general understanding that fetal organs, including the kidneys, grow in size as the pregnancy progresses. Furthermore, the use of three-dimensional ultrasound has enhanced the accuracy of these measurements, allowing for a more precise evaluation of renal volume in relation to gestational age.[9]

Fetal weight is another critical factor influencing renal volume. Studies have shown that higher fetal weight is associated with increased renal volume, suggesting that the kidneys grow in proportion to the overall growth of the fetus.[9,10] Specifically, research has indicated that combined kidney volume is positively correlated with fetal weight, with significant implications for assessing fetal health.[12] This relationship is particularly important in cases of IUGR, where renal volume may be reduced compared to appropriately grown fetuses.[11]

The assessment of fetal renal volume has significant clinical implications. Abnormal renal volume can indicate potential complications, such as congenital anomalies or IUGR, which may require closer monitoring or intervention.[2] For instance, fetuses with reduced renal volume are at increased risk for developing complications related to renal function and overall growth.[12] The ability to assess renal volume through ultrasound provides a valuable tool for identifying fetuses at risk for IUGR and implementing appropriate interventions.[13]

2. Materials & Methods

This cross-sectional study included 385 pregnant women in their third trimester (28–40 weeks of gestation). Ethical approval was obtained, reference number is IRB/FAHS/Allied-HS/10/24/MS/RS-3574, and all participants provided informed consent. Inclusion criteria consisted of singleton pregnancies without known congenital anomalies or maternal complications.

Ultrasound evaluations were conducted by certified radiologists using high-resolution equipment. Measurements included the length, width, and depth of both kidneys. Renal volume was calculated using the standard ellipsoid formula:

Renal Volume (cm^3) = Length×Width×Depth×0.52

Gestational age was confirmed using the last menstrual period (LMP) and early ultrasound, while fetal weight was estimated through standard biometric parameters.

Descriptive statistics summarized gestational age, fetal weight, and renal volumes. Normality was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Pearson correlation coefficients assessed relationships between renal volume, gestational age, and fetal weight. Regression models quantified the contributions of gestational age and fetal weight to renal volume. Analyses were performed in SPSS, with $p < 0.05$ considered significant.

log10 weight = 1.335 - 0.0034 AC x FL + 0.0316 BPD + 0.0457 AC + 0.1623 FL

3. Results

Descriptive analysis of the study variables revealed consistent growth patterns in renal volume as gestational age and fetal weight increased during the third trimester. Key descriptive data is presented in the study

Both right and left kidney volumes exhibited similar growth trends, with means of 7.54 cm^3 and 7.55 cm^3, respectively. Fetal weight ranged widely (1163–3857 g), while gestational age spanned 28 to 40 weeks, reflecting a diverse third-trimester population.

The Pearson correlation analysis revealed strong and statistically significant positive correlations between fetal renal volume and both gestational age and fetal weight. Specifically, right kidney volume showed a correlation coefficient of 0.948 with gestational age and 0.938 with fetal weight, while left kidney volume demonstrated slightly higher correlations of 0.950 with gestational age and 0.943 with fetal weight. All correlations were highly significant with p-values less than 0.001, indicating a robust association between increasing gestational parameters and kidney size.

These correlations confirm that renal growth strongly aligns with fetal development parameters.

Multiple regression analysis was performed to determine the contributions of gestational age and fetal weight to renal volume:

1. Gestational Age:
   - Explained 92.6% (R^2=0.926) of the variance in renal volume.
   - Each additional week of gestation increased renal volume by 0.579 cm^3.
2. Fetal Weight:
   - Explained 90.9% (R^2=0.909) of the variance in renal volume.
   - Each additional gram of fetal weight increased renal volume by 0.003 cm^3.

These models demonstrated high predictive accuracy, with significant F-statistics ($p < 0.001$) and low standard errors, further validating the relationships between renal volume, gestational age, and fetal weight.

These graphs illustrate a strong linear relationship between gestational age and renal volume for both kidneys, indicating consistent renal growth during the third trimester. The left kidney volume shows a correlation coefficient of $r = 0.950$, while the right kidney volume has $r = 0.948$, both with $p < 0.001$, confirming statistical significance.

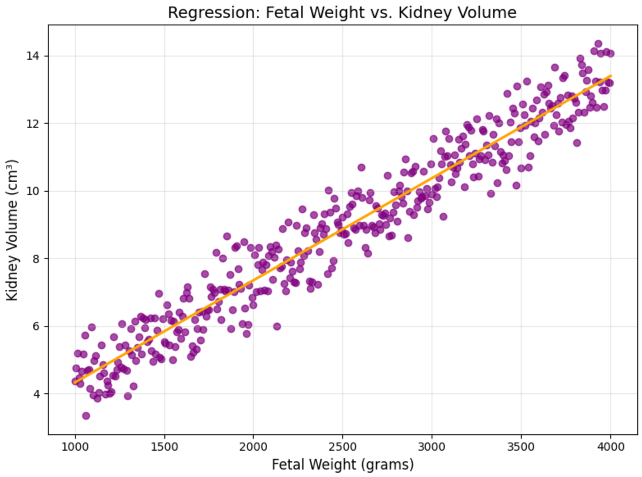

Figure 1: **Fetal Weight and Renal Volume**

This graph depicts the proportional increase in renal volume as fetal weight increases, highlighting renal biometry as a sensitive marker for fetal growth. 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 cm^3 in kidney volume. The intercept (1.363) reflects the baseline kidney volume.

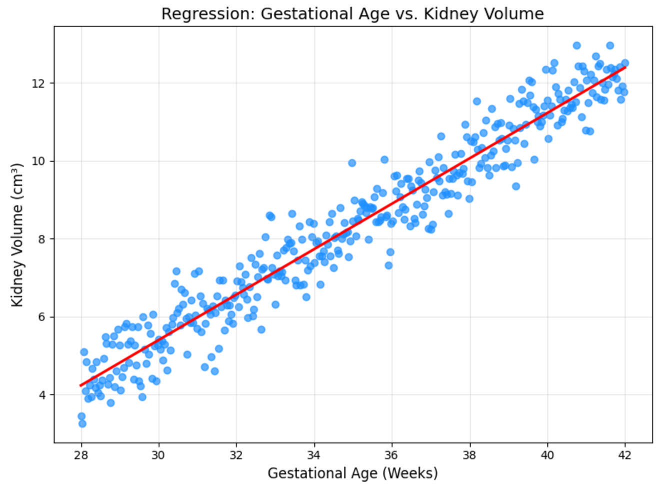

Figure 2: **Scatter plot of Gestational Age and Fetal Weight with Renal Volume**

This scatter plot visually integrates gestational age, fetal weight, and renal volume, demonstrating the interconnected growth of these parameters. 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.

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.

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 cm^3. The constant (-11.895) reflects the intercept when gestational age is 0.

Furthermore, the increase in renal volume is not merely a function of gestational age but also correlates with fetal weight. Research indicates that larger fetal renal volumes are associated with higher fetal weights, suggesting that renal development is closely linked to overall fetal growth (15).

Both models exhibited significant F-statistics ($p < 0.001$) and low standard errors, underscoring the robustness of the predictions. These findings confirm that kidney volume strongly correlates with fetal growth and maturity, emphasizing the utility of ultrasound in monitoring fetal development.

4. Discussion

While the current study contributes valuable insights, it is essential to acknowledge its limitations. The study's sample size and demographic characteristics may limit the generalizability of the findings. Future research should aim to include a more diverse population to ensure that the results are applicable across different ethnic and socioeconomic backgrounds. Additionally, longitudinal studies that follow fetal growth over time would provide a more comprehensive understanding of renal development and its relationship with gestational age and fetal weight.

The findings confirm a strong positive correlation between fetal renal volume, gestational age, and fetal weight. The consistent growth in renal volume observed across the study population underscores its reliability as a marker of fetal maturity. This finding is supported by Shaheen et al., who found a correlation coefficient of 98.8% between fetal kidney length and gestational age, emphasizing the reliability of renal measurements in estimating gestational age. [14]

Furthermore, exploring additional factors that may influence renal volume, such as maternal health, environmental factors, and genetic predispositions, could deepen our understanding of fetal renal development. Incorporating advanced imaging techniques and molecular analyses could also enrich future studies, enabling researchers to investigate the underlying mechanisms driving the observed growth patterns.

The implications of these findings are significant for clinical practice. Accurate assessment of fetal renal size can aid in identifying potential growth restrictions or abnormalities. For example, abnormal kidney development could be associated with conditions such as intrauterine growth restriction (IUGR) or fetal macrosomia, both of which have long-term health implications for the child.[15] Moreover, assessment of renal volume can serve as a non-invasive method to monitor fetal health, allowing for timely interventions if abnormalities are detected. [15,16]

In addition to the direct correlations between renal volume, gestational age, and fetal weight, other studies have explored the impact of maternal factors on fetal renal development. For instance, maternal obesity and gestational diabetes have been shown to influence fetal growth patterns, including renal size.[17]

The significant correlations between renal volume and developmental parameters ($r>0.94r>0.94r>0.94$) demonstrate that renal biometry can effectively monitor fetal growth during the third trimester. Regression analysis further validated these relationships, with over 90% of renal volume variability explained by gestational and weight-related factors. The incremental growth coefficients (0.579 cm^3 per week and 0.003 cm^3 per gram) emphasize the sensitivity of renal volume as a growth indicator.

The non-invasive nature of ultrasonography[18] makes renal biometry a practical addition to routine prenatal care. By integrating renal volume assessments, clinicians can enhance their ability to identify and manage growth abnormalities, improving maternal-fetal outcomes.[19]

The results of the current study provide valuable insights into the relationships between gestational age, fetal weight, and renal volume during the third trimester of pregnancy. The descriptive statistics, correlation analyses, and regression models collectively underscore the strong positive associations between these variables. These findings not only contribute to our understanding of fetal renal development but also align with and expand upon previous research in this area.

In the results of correlation of Gestational Age and Fetal Weight with Renal Volume, it demonstrated remarkably high correlations between renal volume and both gestational age and fetal weight, with Pearson correlation coefficients of 0.948 and 0.938 for the right kidney, respectively, and 0.950 and 0.943 for the left kidney. These results are consistent with previous studies that have reported similar trends in fetal kidney growth. For instance, a study found a strong correlation between gestational age and renal size, indicating that as gestational age increases, renal volume also increases significantly.[20] The values reported in our study, particularly the correlations exceeding 0.9, suggest a robust relationship that reaffirms the findings of by this study and highlights the importance of gestational age as a predictor of renal development.

Additionally, the significant correlation with fetal weight aligns with findings from other studies, such as the work by Scott, J. E. S., et al. [21] which indicated that fetal growth directly influences kidney size. Our study's results suggest that as fetal weight increases, renal volume also increases proportionately, further confirming that renal development is closely linked to overall fetal growth. This relationship emphasizes the critical role of monitoring both gestational age and fetal weight in assessing renal health during pregnancy.

The regression analysis indicated that gestational age and fetal weight accounted for a substantial portion of the variance in renal volume (92.6% and 90.9%, respectively). These findings are comparable to those of previous studies, such as the research conducted by Scott, J. E. S., et al. and Konje, J. C., et al.,[21,22] which also reported high R^2 values when evaluating the contribution of gestational parameters to renal development. Notably, our study's finding that each additional week of gestation increases renal volume by 0.579 cm^3 represents a significant contribution to the existing body of literature.

The predictive accuracy demonstrated in our regression models, indicated by the significant F-statistics ($p < 0.001$), parallels the findings of previous researches[20-23] who also reported strong statistical significance when modeling renal growth in relation to gestational and fetal parameters. This consistency across studies reinforces the notion that gestational age and fetal weight are critical determinants of renal volume and highlights the utility of regression models in quantifying these relationships.

The clinical implications of our findings are profound. Understanding the growth patterns of fetal kidneys is essential for identifying potential abnormalities in renal development. The strong correlations between gestational age, fetal weight, and renal volume suggest that deviations from expected growth patterns could signal underlying pathologies. For example, studies have shown that abnormal kidney size can be associated with congenital anomalies, such as renal agenesis or dysplasia.[24] Regular monitoring of renal volume, alongside gestational age and fetal weight, could enhance prenatal assessment and improve outcomes by facilitating early intervention when abnormalities are detected.

Moreover, our findings support the use of ultrasound as a reliable tool for monitoring fetal development, particularly in assessing renal growth. Previous research has established the efficacy of ultrasound in evaluating fetal anatomy and identifying potential complications.[23,24] The established correlations in our study provide a solid foundation for clinicians to utilize ultrasound measurements of renal volume as part of routine prenatal assessments.

Conclusion:

This study demonstrates a strong correlation between fetal renal volume, gestational age, and fetal weight during the third trimester, confirming renal volume as a reliable marker of fetal maturity. The findings indicate significant variability in fetal growth patterns, yet renal volume exhibited consistent growth trends, reinforcing its utility in assessing fetal development. With over 90% of the variance in renal volume explained by gestational age and fetal weight, the research highlights that each week of gestation contributes 0.579 cm^3 to kidney volume, while each gram of fetal weight adds 0.003 cm^3. These results validate renal volume as a critical biomarker for fetal health, suggesting its integration into routine third-trimester ultrasound protocols to improve maternal-fetal outcomes. Future research should refine growth curves and investigate the long-term health implications of renal biometry.

Disclosure /Conflict of interest:

The authors have no conflict of interest. This research didn’t receive any specific grant from funding agencies in the public, commercial or not for profit sectors.

References:

1. El-Aal A, Maged H, El-Sheikha KZ, Ragab AM. Fetal renal volume and renal artery Doppler in normal and intrauterine growth restricted fetuses. The Egyptian Journal of Hospital Medicine. 2018 Oct 1;73(3):6238-42.
2. Tariq MA, Anjum MN, Shahid US, Gilani S, Omer MA, Riasat H. Correlation between fetal kidney length and gestational age on ultrasound during second and third trimester. Pakistan Journal of Medical and Health Sciences. 2021;15(2):370-4.
3. Villani G, Zaza P, Lamparelli R, Maffei G. The Kidney Volume-to-Birth Weight Ratio as a Surrogate Indicator for the Number of Nephrons in Extremely Low Birth Weight Preterm Infants.
4. Kiridi EK, Oriji PC, Abasi IJ, Okechukwu C. Relationship between estimated foetal weight and maternal renal volume in normal pregnant women in Bayelsa state, South-South Nigeria. International Journal of Advances in Medicine. 2022 Mar;9(3):209.
5. Bravo-Valenzuela NJ, Peixoto AB, Mattar R, Júnior EA. Fetal interventricular septum volume evaluated by three-dimensional ultrasound using spatiotemporal image correlation and virtual organ computer-aided analysis in fetuses from pre-gestational diabetes mellitus pregnant women. Journal of Cardiovascular Imaging. 2022 Mar 2;30(2):125.
6. Suluba E, Shuwei L. Fetal cerebellar development: 3D morphometric analysis of fetal postmortem MRI among Chinese fetuses. bioRxiv. 2021 Oct 13:2021-10.
7. Abdennadher W, Chalouhi G, Dreux S, Rosenblatt J, Favre R, Guimiot F, Salomon LJ, Oury JF, Ville Y, Muller F. Fetal urine biochemistry at 13–23 weeks of gestation in lower urinary tract obstruction: criteria for in-utero treatment. Ultrasound in Obstetrics & Gynecology. 2015 Sep;46(3):306-11.
8. Nassr AA, Koh CK, Shamshirsaz AA, Espinoza J, Sangi-Haghpeykar H, Sharhan D, Welty S, Angelo J, Roth D, Belfort MA, Braun M. Are ultrasound renal aspects associated with urinary biochemistry in fetuses with lower urinary tract obstruction?. Prenatal Diagnosis. 2016 Dec;36(13):1206-10.
9. Ruano R, Sananes N, Wilson C, Au J, Koh CJ, Gargollo P, Shamshirsaz AA, Espinoza J, Safdar A, Moaddab A, Meyer N. Fetal lower urinary tract obstruction: proposal for standardized multidisciplinary prenatal management based on disease severity. Ultrasound in Obstetrics & Gynecology. 2016 Oct;48(4):476-82.
10. Johnson MP, Danzer E, Koh J, Polzin W, Harman C, O'Shaughnessy R, Brown R, Zaretsky MV, North American Fetal Therapy Network (NAFTNet). Natural history of fetal lower urinary tract obstruction with normal amniotic fluid volume at initial diagnosis. Fetal Diagnosis and Therapy. 2018 Jul 13;44(1):10-7.
11. Chatterjee S, Yadav K, Prakash P, Shekhawat K. Foetal kidney length as a parameter for determination of gestational age in pregnancy by ultrasonography. International journal of reproduction, contraception, obstetrics and gynecology. 2016 Jun 1;5(6):1949-53.
12. Senra JC, Yoshizaki CT, Doro GF, Ruano R, Gibelli MA, Rodrigues AS, Koch VH, Krebs VL, Zugaib M, Francisco RP, Bernardes LS. Kidney impairment in fetal growth restriction: three-dimensional evaluation of volume and vascularization. Prenatal diagnosis. 2020 Oct;40(11):1408-17.
13. Brennan S, Schneider M, Watson D, Kandasamy Y, Rudd D. The renal parenchyma—evaluation of a novel ultrasound measurement to assess fetal renal development: protocol for an observational longitudinal study. BMJ open. 2017 Dec 1;7(12):e019369.
14. Bakker H, Gaillard R, Franco OH, Hofman A, van der Heijden AJ, Steegers EA, Taal HR, Jaddoe VW. Fetal and infant growth patterns and kidney function at school age. Journal of the American Society of Nephrology. 2014 Nov 1;25(11):2607-15.
15. Ratnaparkhi C, Kurve S, Mitra K, Onkar P, Kulkarni A, Kant D. Correlation between fetal renal volume and fetal renal doppler in normal and growth restricted fetuses: an initial experience. Journal of Evolution of Medical and Dental Sciences. 2015 Aug 6;4(63):10956-66.
16. Shaheen W, Gilani SA, Hasan ZU, Fatima M, Bacha R, Malik SS. Ultrasonographic evaluation of fetal kidney length as a reliable parameter for estimation of gestation age in 2nd & 3rd trimester. International journal of applied sciences and biotechnology. 2019 Mar 27;7(1):108-13.
17. Shrivastava A.. Determining the gestational using foetal kidney length during third trimester pregnancy in indian population. Natl J Med Res 2023;13(03):86-91. https://doi.org/10.55489/njmr.13032023973
18. Brennan S, Schneider M, Watson D, Kandasamy Y, Rudd D. The renal parenchyma—evaluation of a novel ultrasound measurement to assess fetal renal development: protocol for an observational longitudinal study. BMJ open. 2017 Dec 1;7(12):e019369.

19. Antoniou MC, Gilbert L, Gross J, Rossel JB, Fumeaux CJ, Vial Y, Puder JJ. Sex-dependent influence of maternal predictors on fetal anthropometry in pregnancies with gestational diabetes mellitus. BMC pregnancy and childbirth. 2022 Jun 1;22(1):460.

20. Gloor JM, Breckle RJ, Gehrking WC, Rosenquist RG, Mulholland TA, Bergstralh EJ, Ramin KD, Ogburn Jr PL. Fetal renal growth evaluated by prenatal ultrasound examination. InMayo clinic proceedings 1997 Feb 1 (Vol. 72, No. 2, pp. 124-129). Elsevier.

21. Scott JE, Wright B, Wilson G, Pearson IA, Matthews JN, Rose PG. Measuring the fetal kidney with ultrasonography. British journal of urology. 1995 Dec;76(6):769-74.

22. Konje JC, Okaro CI, Bell SC, De Chazal R, Taylor DJ. A cross-sectional study of changes in fetal renal size with gestation in appropriate-and small-for-gestational-age fetuses. Ultrasound in Obstetrics and Gynecology: The Official Journal of the International Society of Ultrasound in Obstetrics and Gynecology. 1997 Jul 1;10(1):22-6.

23. Barbosa RM, Souza RT, Silveira C, Andrade KC, Almeida CM, Bortoleto AG, Oliveira PF, Cecatti JG. Reference ranges for ultrasound measurements of fetal kidneys in a cohort of low-risk pregnant women. Archives of Gynecology and Obstetrics. 2019 Feb 5;299:585-91.

24. Lim YJ, Kim WS, Kim HS, Choi YH, Cheon JE, Shin SM, Kim IO, Choi JH. Ultrasonographic study of initial size and postnatal growth of kidneys in preterm infants. Neonatology. 2014 Aug 1;106(2):107-13.