International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Ultrasonographic Assessment of Fetal Growth Patterns and Their Association with Maternal Risk Factors: A Prospective Observational Study

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Received: 15-01-2026
Accepted: 19-02-2026
Published: 21-02-2026

ABSTRACT

Background: Serial obstetric ultrasonography enables objective monitoring of fetal biometry and supports timely recognition of abnormal growth trajectories.
Objectives: To describe third-trimester fetal growth patterns on ultrasound and examine their association with maternal risk factors.
Methods: In this prospective observational study, 100 pregnant women were enrolled and followed until delivery. Standardized fetal biometry (BPD, HC, AC, FL) and EFW were recorded on serial scans, with umbilical artery Doppler assessment in the final evaluation. Fetuses were categorized as appropriate, small, or large for gestational age using centile-based definitions. Maternal anemia, gestational hypertension, GDM, and undernutrition were documented from antenatal records.
Results: The mean maternal age was 26.9 ± 4.3 years and the mean gestational age at recruitment was 21.8 ± 4.6 weeks. On the final scan, 68% of fetuses were appropriate for gestational age, 22% were SGA, and 10% were LGA. Reduced AC was the most frequent finding among SGA fetuses (81.8%), and elevated umbilical artery pulsatility index was observed in 36.4%. SGA occurred more often among anemic women (42.1%) than among non-anemic women (9.7%), while LGA was more frequent among women with GDM (33.3%) than among those without diabetes (4.9%).
Conclusion: Maternal anemia and hypertensive disorders clustered with growth restriction patterns, whereas GDM was linked to fetal overgrowth. Combining maternal risk profiling with serial biometry and Doppler supports antenatal risk stratification.

Keywords*:* Fetal growth; Ultrasonography; Small for gestational age; Gestational diabetes; Umbilical artery Doppler.

INTRODUCTION

Fetal growth reflects the interaction between genetic potential, placental function, and the maternal metabolic and vascular environment [1]. Deviations from expected growth trajectories are clinically important because they are associated with stillbirth, neonatal morbidity, and longer-term neurodevelopmental and cardiometabolic risk[2]. Contemporary obstetric guidance recognizes fetal growth restriction (FGR) as a major contributor to preventable perinatal harm and recommends systematic identification of at-risk pregnancies with structured surveillance and timely intervention [3,4].

Ultrasonography is the cornerstone of antenatal growth assessment. Standardized fetal biometry-biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL)-supports estimation of fetal weight and longitudinal assessment of centile trajectories. Composite formulas combining head, abdominal, and femoral measurements remain widely used for estimated fetal weight (EFW) calculation [3]. Longitudinal standards based on serial ultrasound measurements, such as those from the INTERGROWTH-21st Project, enable consistent classification of small for gestational age (SGA) and large for gestational age (LGA) categories across gestational ages [2]. Professional guidance further reinforces standard planes, caliper placement, and reporting to reduce measurement error and improve comparability [4].

Interpretation of biometry is strengthened by integrating fetal phenotype and placental function. Reduced AC is often an early biometric signal of nutritional compromise because hepatic glycogen deposition and subcutaneous fat accretion are preferentially affected. Stage-based frameworks for FGR highlight the value of combining growth centiles with Doppler velocimetry to stratify risk, tailor monitoring intervals, and guide timing of delivery [5,6]. Evidence syntheses indicate that umbilical artery Doppler surveillance improves perinatal outcomes in high-risk pregnancies by identifying increased placental resistance and deteriorating fetal condition [7].

Maternal risk factors remain key upstream determinants of fetal growth patterns. Maternal anemia has been associated with increased risk of SGA and low birth weight through reduced oxygen transport and altered placental development [8,9]. Hypertensive disorders contribute to uteroplacental malperfusion and are strongly linked to growth restriction [10]. Conversely, gestational diabetes mellitus is linked to fetal overgrowth and higher rates of LGA and macrosomia [11,12], while maternal undernutrition and low pre-pregnancy body mass index are associated with SGA and related neonatal morbidity [13]. Locally generated data remain important because the distribution of risk factors, timing of ultrasound surveillance, and care pathways differ between institutions.

Objectives: To (i) characterize third-trimester fetal growth categories on ultrasonography using standardized biometry and EFW, (ii) describe predominant biometric patterns among SGA fetuses, and (iii) assess the association of maternal anemia, gestational hypertension, GDM, and maternal undernutrition with fetal growth patterns, Doppler findings, and selected perinatal outcomes.

MATERIALS AND METHODS

Study design and setting: A prospective observational study was conducted in the Department of Radiodiagnosis, Government Medical College, Vikarabad, India, over an 8-month period (May 2025 to December 2025).

Participants and recruitment: Pregnant women attending routine antenatal ultrasonography were enrolled consecutively after written informed consent. Gestational age was determined using the last menstrual period and corroborating early ultrasound records when available. Participants were followed prospectively until delivery, and maternal clinical data were extracted from antenatal case records.

Eligibility criteria: Singleton intrauterine pregnancies were included. Pregnancies with multiple gestation, major fetal structural anomalies detected on ultrasound, or inability to complete follow-up to delivery were excluded.

Ultrasound protocol: Fetal biometry was measured using standardized planes and caliper placement consistent with international guidance [4]. BPD, HC, AC, and FL were recorded at each scan, and EFW was calculated using a composite formula based on these parameters [3]. Serial scans were performed as per clinical schedule, with a mandatory final scan in the third trimester. Umbilical artery Doppler velocimetry was obtained during the final evaluation with the fetus at rest, using a free-floating loop of cord. At least three consecutive uniform waveforms were recorded, and the mean pulsatility index (PI) was documented. An elevated PI (above the gestational age-specific 95th percentile) was treated as abnormal.

Definitions and exposures: On the final scan, fetuses were classified as SGA (EFW <10th percentile), AGA (10th-90th percentile), or LGA (EFW >90th percentile) using centile-based definitions [1,2]. Maternal risk factors were predefined and recorded from antenatal notes: anemia (hemoglobin <11 g/dL), gestational hypertension (new-onset blood pressure ≥140/90 mmHg after 20 weeks), gestational diabetes mellitus (GDM; diagnosed per institutional glucose testing protocol), and maternal undernutrition (body mass index <18.5 kg/m^2). Presence of multiple risk factors was documented when two or more conditions co-existed.

Outcomes and statistical analysis: The primary outcome was third-trimester fetal growth category (AGA/SGA/LGA). Secondary outcomes included predominant biometric pattern among SGA fetuses (e.g., reduced AC), Doppler abnormality, and selected perinatal outcomes (birth weight category and neonatal intensive care unit admission). Continuous variables were summarized as mean ± standard deviation and categorical variables as number (percentage). For key 2×2 comparisons, associations were evaluated using tests for proportions; a two-sided p value <0.05 was considered statistically significant. Data were entered into a password-protected spreadsheet and analyzed using standard statistical software. Analyses were performed on a complete-case basis because follow-up was available for all enrolled participants.

Ethical considerations and reporting: The study protocol was approved by the Institutional Ethics Committee of Government Medical College, Vikarabad. Written informed consent was obtained from all participants prior to enrollment. Data confidentiality was maintained by de-identification. The manuscript was prepared in accordance with STROBE recommendations for observational studies [14].

RESULTS

A total of 100 pregnant women were enrolled and followed prospectively until delivery. The mean maternal age was 26.9 ± 4.3 years (range 19-38), and the mean gestational age at recruitment was 21.8 ± 4.6 weeks. Most participants were multiparous (58%), while 42% were primigravidae (Table 1).

Table 1. Baseline maternal characteristics (N = 100)

Characteristic	**Value**
Maternal age (years), mean ± SD	26.9 ± 4.3 (range 19-38)
Gestational age at recruitment (weeks), mean ± SD	21.8 ± 4.6
Parity	
Primigravidae, n (%)	42 (42.0)
Multiparous, n (%)	58 (58.0)

Maternal anemia was recorded in 38% of women, gestational hypertension in 22%, gestational diabetes mellitus (GDM) in 18%, and maternal undernutrition (BMI <18.5 kg/m²) in 16%. Two or more risk factors co-existed in 21% of pregnancies (Table 2).

Table 2. Maternal risk factors (N = 100)

Risk factor	**n (%)**
Anemia	38 (38.0)
Gestational hypertension	22 (22.0)
Gestational diabetes mellitus	18 (18.0)
Undernutrition (BMI <18.5 kg/m²)	16 (16.0)
Multiple risk factors (≥2)	21 (21.0)

Serial ultrasonographic biometry was obtained for BPD, HC, AC, and FL. At the third-trimester assessment, 68% of fetuses were appropriate for gestational age (AGA), 22% were small for gestational age (SGA), and 10% were large for gestational age (LGA) (Table 3). Among SGA fetuses, reduced AC was the most frequent affected parameter (81.8%), followed by EFW below the 10th percentile (77.3%).

Table 3. Third-trimester fetal growth categories and common SGA biometric findings

Parameter	**Value**
Growth category (N = 100)	
Appropriate for gestational age (AGA), n (%)	68 (68.0)
Small for gestational age (SGA), n (%)	22 (22.0)
Large for gestational age (LGA), n (%)	10 (10.0)
Among SGA fetuses (n = 22)	
Reduced abdominal circumference, n (%)	18 (81.8)
EFW <10th percentile, n (%)	17 (77.3)

A statistically significant association was observed between maternal anemia and SGA. Among anemic mothers, 42.1% had SGA fetuses compared to 9.7% among non-anemic mothers ($p < 0.01$) (Table 4). Gestational hypertension was strongly associated with an asymmetric growth-restriction phenotype; 54.5% of hypertensive mothers demonstrated reduced AC with relatively preserved HC. GDM was significantly associated with LGA; 33.3% of women with GDM had LGA fetuses compared to 4.9% among women without diabetes ($p < 0.01$). Maternal undernutrition was predominantly associated with a symmetric restriction phenotype, observed in 62.5% of undernourished women.

Table 4. Association of selected maternal risk factors with fetal growth categories

Exposure	**Outcome**	**Yes, n/N (%)**	**No, n/N (%)**	**p value**
Maternal anemia	SGA	16/38 (42.1)	6/62 (9.7)	<0.01
Gestational diabetes mellitus	LGA	6/18 (33.3)	4/82 (4.9)	<0.01

The mean EFW at the final scan was 2,640 ± 420 g. SGA fetuses had a significantly lower mean EFW (2,120 ± 310 g) compared with AGA fetuses (2,780 ± 360 g) (Table 5). Abnormal umbilical artery Doppler indices (elevated PI) were noted in 36.4% of SGA fetuses, and this finding clustered with hypertensive disorders.

Table 5. Estimated fetal weight and umbilical artery Doppler findings at final scan

Measure	**SGA (n=22)**	**AGA (n=68)**	**Overall (N=100)**
EFW (g), mean ± SD	2,120 ± 310	2,780 ± 360	2,640 ± 420

Abnormal umbilical artery PI, n (%)	8 (36.4)	-	-

Among SGA fetuses, 31.8% required neonatal intensive care unit (NICU) admission compared with 7.4% of AGA fetuses (Table 6). Low birth weight (<2.5 kg) was more frequent in pregnancies complicated by maternal anemia and hypertension. LGA fetuses were associated with a higher incidence of cesarean delivery, particularly among mothers with GDM.

Table 6. NICU admission by fetal growth category

Growth category	NICU admission, n/N (%)
SGA	7/22 (31.8)
AGA	5/68 (7.4)
LGA	-

DISCUSSION

In this prospective cohort, 22% of fetuses were classified as SGA on the third-trimester evaluation, and reduced AC was the dominant biometric feature. This pattern is biologically plausible because hepatic glycogen deposition and subcutaneous fat accretion are preferentially affected during uteroplacental insufficiency, producing an asymmetric phenotype. The observed distribution of AGA, SGA, and LGA provides a pragmatic snapshot of growth burden in routine tertiary antenatal practice and underscores the need for risk-based surveillance rather than reliance on fundal height alone [1,4].

Maternal anemia demonstrated a strong association with SGA, with over two-fifths of anemic women having an SGA fetus. Meta-analytic evidence supports this association and indicates higher SGA and low-birth-weight risk among anemic mothers, particularly when anemia is moderate to severe or persists across gestation [8,9]. Reduced oxygen-carrying capacity and iron-dependent placental growth can plausibly limit nutrient transfer, leading to slowed somatic growth. From a clinical standpoint, this highlights the importance of early anemia detection, adherence to iron supplementation, and closer growth surveillance in anemic pregnancies.

Gestational hypertension in this study clustered with an asymmetric restriction phenotype and with Doppler abnormalities, consistent with uteroplacental malperfusion. Stage-based approaches to FGR emphasize combining biometric centiles with Doppler indices to stratify risk and inform monitoring and delivery decisions [5,6]. Abnormal umbilical artery PI was observed in 36.4% of SGA fetuses, a clinically meaningful proportion given evidence that Doppler surveillance in high-risk pregnancies improves perinatal outcomes [7]. Our findings therefore support incorporating Doppler evaluation when SGA or suspected FGR is identified, especially in the context of hypertensive disease.

In contrast, GDM was associated with fetal overgrowth, with one-third of women with GDM having an LGA fetus. Large population studies have shown that maternal hyperglycemia increases fetal adiposity, macrosomia, and cesarean delivery risk [11,12]. Even when glucose is treated, residual risk can persist, reinforcing the value of third-trimester growth assessment to anticipate delivery complications. Maternal undernutrition was more often associated with a symmetric restriction phenotype in our cohort, consistent with evidence linking low pre-pregnancy BMI to SGA and related morbidity [13]. Finally, NICU admission was substantially higher among SGA fetuses, suggesting that ultrasound-defined growth patterns have meaningful downstream clinical correlates. Together, these results support integrated antenatal care pathways that combine maternal risk profiling, standardized biometry, and Doppler when indicated.

The prospective design and complete follow-up strengthen internal validity, and the use of standardized measurement technique aligns with international guidance [14]. Nevertheless, the study was not intended to generate population reference centiles, and the findings should be interpreted as associations within a tertiary care cohort. Future work with larger samples and multivariable modeling could better quantify independent effects of overlapping risk factors and evaluate whether combining EFW centiles with Doppler improves prediction of adverse outcomes beyond clinical risk factors alone.

Limitations

This single-center study included 100 participants from a tertiary care hospital, so estimates reflect a referred clinical population and not the community. Growth categorization relied on ultrasound-based centiles and EFW formulas, which carry inherent measurement variability despite standardized technique. Numbers for some delivery outcomes, including mode of delivery and birth trauma, were not captured in analyzable categories, limiting outcome granularity.

CONCLUSION

This prospective observational study demonstrated that third-trimester ultrasound can meaningfully characterize fetal growth patterns and their clinical correlates. In our cohort, SGA was common and typically manifested as reduced abdominal circumference, with Doppler abnormalities in a substantial subset. Maternal anemia and hypertensive disorders showed strong associations with growth restriction phenotypes and adverse neonatal utilization, while GDM was linked to fetal overgrowth. These findings support a practical antenatal approach that integrates routine screening for anemia, hypertension, diabetes, and nutritional status with serial standardized biometry and selective umbilical artery Doppler. Such integration can guide surveillance intensity, counseling, and timely referral for high-risk pregnancies. This strategy strengthens perinatal planning in busy tertiary settings**.**

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