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Article

Prevalence of Small for Gestational Age Foetuses Using Hadlock Method: An Exploration of Associated Risk Factors

Kanwal Bano[1], Sayed Maghfoor Ullah[1], Fazal Haq[1], Bashir Ullah[1], Aqal Zaman[2], Muhammad Shahzeb[1], Rizwan Ullah[1]

1. Institute of Paramedical Sciences, Khyber Medical University, Peshawar, Pakistan
2. Department of Microbiology and Molecular Genetics, Bahauddin Zakariya University, Multan, Pakistan

Correspondence:
rizwan.ipms@kmu.edu.pk

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ABSTRACT

Background: Small for gestational age (SGA) foetuses are associated with increased perinatal morbidity and long-term developmental challenges. In low-resource settings, limited data exists on region-specific prevalence and maternal risk factors contributing to SGA, particularly using validated biometric estimation methods like the Hadlock formula. **Objective:** This study aimed to determine the prevalence of SGA foetuses using the Hadlock method and explore its association with maternal risk factors, specifically passive tobacco exposure, haemoglobin levels, and systolic blood pressure. **Methods:** A prospective cross-sectional study was conducted at the Radiology Department of Mardan Medical Complex, Khyber Pakhtunkhwa, Pakistan, between July 1, 2022, and February 8, 2023. A total of 251 third-trimester pregnant women aged 18–45 years with singleton pregnancies were enrolled. Participants with multiple gestations, cardiac or neurological conditions, ruptured membranes, or TORCH positivity were excluded. Foetal biometric measurements (BPD, HC, AC, FL) were obtained using ultrasound to estimate foetal weight via the Hadlock method. Data were analyzed using SPSS version 27, with chi-square and binary logistic regression applied to evaluate associations. Ethical approval was obtained from the Khyber Medical University Ethics Board (DIR/ORIC/Ref/23/00013), in compliance with the Declaration of Helsinki. **Results:** The prevalence of SGA foetuses was 10.4% (n=26), while 89.6% (n=224) had normal estimated foetal weight. Passive smoking was reported in 19.6% (n=49) and showed a strong association with SGA ($p = 0.000$). Low maternal haemoglobin levels were also significantly associated with SGA ($p = 0.005$), with an odds ratio of 0.63 indicating increased risk. No significant association was found between maternal systolic blood pressure and SGA ($p = 0.205$). **Conclusion:** The study identified a notable prevalence of SGA foetuses using the Hadlock method and highlighted maternal tobacco exposure and low haemoglobin levels as significant modifiable risk factors. These findings underscore the importance of integrating routine ultrasound and maternal health assessments into antenatal care to reduce the burden of SGA and improve neonatal outcomes in resource-limited settings.

Keywords: Small for Gestational Age, Hadlock Method, Foetal Biometry, Maternal Haemoglobin, Passive Smoking, Ultrasonography, Prenatal Risk Assessment.

INTRODUCTION

Small for gestational age (SGA) refers to infants whose birth weight is below the 10th percentile for their gestational age, indicating restricted growth during the intrauterine period (1). This classification is based solely on weight at birth and does not necessarily reflect the underlying intrauterine growth trajectory or any physical anomalies (2). SGA infants face elevated risks of perinatal mortality, neonatal complications, and long-term adverse health outcomes, including metabolic syndrome, cardiovascular disease, and impaired neurodevelopmental performance (3). Identifying the factors that contribute to SGA is essential for improving prenatal care and mitigating the associated risks.

One of the most frequently cited modifiable risk factors for SGA is maternal tobacco exposure. Research consistently demonstrates a strong link between active or passive smoking during pregnancy and impaired fetal growth, with maternal smoking increasing the risk of SGA infants by two to three times (3). Other studies have shown that smoking disrupts placental function, leading to reduced oxygen and nutrient supply to the

developing fetus (3). Additionally, maternal haemoglobin (Hb) level plays a significant role in fetal development. Anemia during pregnancy has been associated with low birth weight and increased likelihood of SGA, presumably due to diminished oxygen-carrying capacity of the blood, which compromises fetal oxygenation (16). However, high maternal haemoglobin concentrations have also been implicated in adverse outcomes, indicating a need to understand the nuanced relationship between Hb levels and fetal growth (16).

While maternal blood pressure, particularly pre-eclampsia and chronic hypertension, is well-documented as a risk factor for intrauterine growth restriction (IUGR), the evidence regarding its role in predicting SGA births remains inconclusive. Some findings suggest that persistent maternal hypotension could lead to poor placental perfusion and subsequent foetal underdevelopment, although this association is not consistently observed across studies (15). Moreover, socioeconomic, nutritional, and environmental factors, as well as maternal health conditions, contribute to the heterogeneity in SGA prevalence observed across different geographical settings (5,11). Despite extensive research, variability in methodological approaches, including the use of different foetal growth standards and measurement techniques, limits the comparability of findings and underscores the need for standardized diagnostic criteria. Ultrasonography remains the cornerstone for foetal biometry and estimation of foetal weight during gestation. The Hadlock method, which incorporates measurements such as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL), is widely accepted for estimating gestational age and expected foetal weight (4,6,10).

Nevertheless, there is a lack of regional data employing this method to assess the frequency of SGA and its association with modifiable maternal risk factors in the Pakistani population, particularly in Khyber Pakhtunkhwa. Existing literature has primarily focused on either birth outcomes or retrospective clinical records, with limited prospective studies assessing SGA using biometric ultrasound parameters during the third trimester. Given these gaps, the present study aims to determine the frequency of SGA foetuses using the Hadlock method and to investigate its association with selected maternal risk factors, including tobacco exposure, haemoglobin level, and systolic blood pressure. By focusing on a third-trimester pregnant population in a clinical setting, this study seeks to contribute region-specific data to the broader discourse on prenatal risk assessment and foetal health. The central research question is: What is the prevalence of small for gestational age foetuses using the Hadlock method, and how are maternal smoking, haemoglobin levels, and systolic blood pressure associated with this condition?

MATERIAL AND METHODS

This study employed a prospective cross-sectional observational design to investigate the prevalence of small for gestational age (SGA) foetuses and their association with maternal risk factors using the Hadlock method. The study was conducted at the Radiology Department's obstetrics unit of Mardan Medical Complex, Khyber Pakhtunkhwa, Pakistan, from July 1, 2022, to February 8, 2023. The study population consisted of pregnant women in their third trimester, aged between 18 and 45 years. Participants were included if they were carrying a singleton pregnancy and undergoing routine obstetric ultrasonography. Women with multiple pregnancies, known cardiac or neurological disorders, ruptured membranes, or positive TORCH profiles were excluded to minimize confounding variables affecting foetal growth. Recruitment was conducted through non-probability convenience sampling. Verbal and written informed consent was obtained from all eligible participants after a thorough explanation of the study objectives and procedures. The study received ethical approval from the Institutional Review Board of Khyber Medical University (IRB approval number: DIR/ORIC/Ref/23/00013) and complied with the principles of the Declaration of Helsinki for research involving human subjects.

The primary outcome of the study was the identification of SGA foetuses, defined as those with an estimated foetal weight (EFW) below the 10th percentile for gestational age, as determined by ultrasound using the Hadlock method. The Hadlock formula incorporates biometric parameters including femur length (FL), biparietal diameter (BPD), head circumference (HC), and abdominal circumference (AC) to estimate foetal weight, and is considered a validated and widely used technique in obstetric imaging (4,10). The secondary outcomes included associations between SGA status and selected maternal variables: tobacco exposure (assessed through self-reported passive smoking), haemoglobin levels (measured in g/dL via routine laboratory testing), and systolic blood pressure (measured in mmHg using a calibrated sphygmomanometer during antenatal visits). All ultrasound measurements were conducted by qualified radiology technicians using standardized obstetric protocols to ensure inter-observer reliability. A predesigned proforma was used for consistent data collection, including maternal age, pregnancy order, and clinical history.

Data was analyzed using SPSS version 27. Descriptive statistics were calculated for all continuous variables and presented as mean ± standard deviation. Frequencies and percentages were computed for categorical variables. To assess the association between categorical variables such as SGA and passive smoking, a chi-square test was applied. For continuous variables, such as haemoglobin levels and systolic blood pressure, binary logistic regression was conducted with EFW as a dichotomous outcome (SGA vs. non-SGA). Odds ratios (OR) and 95% confidence intervals (CI) were calculated to measure the strength of associations. Missing data were minimal; the one non-respondent participant was excluded from inferential analysis to ensure data integrity. No imputation techniques were applied due to the negligible rate of missing values. Potential confounders, such as maternal age and parity, were examined but not found to significantly alter the results and were thus not included in the final regression models. All collected data were anonymized to protect participant confidentiality, with unique identifiers assigned to each participant. The original data sheets were securely stored and accessible only to the principal investigators. This study aimed to ensure methodological rigor, ethical integrity, and reproducibility in examining the impact of

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maternal risk factors on foetal growth in a resource-limited setting.

RESULTS

Out of 251 pregnant women enrolled in the study, 26 (10.4%) were identified as having small for gestational age (SGA) foetuses based on ultrasound-derived estimated foetal weight using the Hadlock method, while 224 (89.6%) had foetuses with normal growth parameters. One participant was non-respondent and excluded from inferential analysis. Among the SGA group, the mean gestational age was 35.3 ± 2.5 weeks, and the most common parity observed was the third pregnancy. In contrast, the non-SGA group had a mean gestational age of 36.5 ± 1.5 weeks and most included women in their second pregnancy.

Table 1 Mean Biometric and Clinical Parameters Among Mothers of SGA Foetuses (n = 26)

Parameter	Mean ± SD
Gestational Age (weeks)	35.3 ± 2.5
Foetal Order (Mode)	3rd pregnancy
Maternal Age (years)	27.1 ± 4.9
Femur Length (cm)	6.6 ± 0.7
Head Circumference (cm)	28.8 ± 2.0
Abdominal Circumference (cm)	28.1 ± 2.6
Biparietal Diameter (cm)	8.3 ± 0.7
Systolic BP (mmHg)	115.7 ± 7.9
Haemoglobin (g/dL)	10.3 ± 1.3

Biometric parameters measured via ultrasonography revealed significantly lower mean values among the SGA group compared to the non-SGA group. Mean femur length (FL), head circumference (HC), abdominal circumference (AC), and biparietal diameter (BPD) were consistently lower in the SGA group. Maternal haemoglobin levels and systolic blood pressure were also measured. The mean Hb in the SGA group was 10.3 ± 1.3 g/dL versus 11.5 ± 6.1 g/dL in the non-SGA group, indicating a statistically significant difference ($p = 0.005$) when analyzed using binary logistic regression. However, no statistically significant association was observed between maternal systolic blood pressure and SGA status ($p = 0.205$). These findings suggest that maternal anemia and passive tobacco exposure are strong, modifiable predictors of SGA foetal development. Ultrasonography using the Hadlock method was effective in identifying growth-restricted foetuses and could serve as a routine prenatal screening tool. Despite systolic BP being traditionally monitored during pregnancy, its predictive value for SGA in this study was not statistically significant, indicating that other markers or cumulative blood pressure profiles might be more relevant.

Table 2 Mean Biometric and Clinical Parameters Among Mothers of Non-SGA Foetuses (n = 224)

Parameter	Mean ± SD
Gestational Age (weeks)	36.5 ± 1.5
Foetal Order (Mode)	2nd pregnancy
Maternal Age (years)	26.5 ± 4.7
Femur Length (cm)	7.1 ± 0.5
Head Circumference (cm)	31.8 ± 18.2
Abdominal Circumference (cm)	31.3 ± 2.2
Biparietal Diameter (cm)	9.3 ± 6.0
Systolic BP (mmHg)	117.4 ± 6.1
Haemoglobin (g/dL)	11.5 ± 6.1

Unexpectedly, even in the absence of hypertensive disorders, a substantial proportion of SGA cases were still observed, pointing toward multifactorial influences, including nutrition and environmental factors. Future research could explore longitudinal data and biomarkers for placental insufficiency to enhance early detection and intervention.

Table 3 Association Between Maternal Factors and SGA Status

Variable	p-value	Statistical Test	Clinical Interpretation
Passive Smoking	0.000	Chi-square Test	Positive association; higher SGA risk in exposed mothers
Haemoglobin Level	0.005	Binary Logistic Regression	Low Hb significantly increases odds of SGA (OR = 0.63)
Systolic Blood Pressure	0.205	Binary Logistic Regression	No significant association

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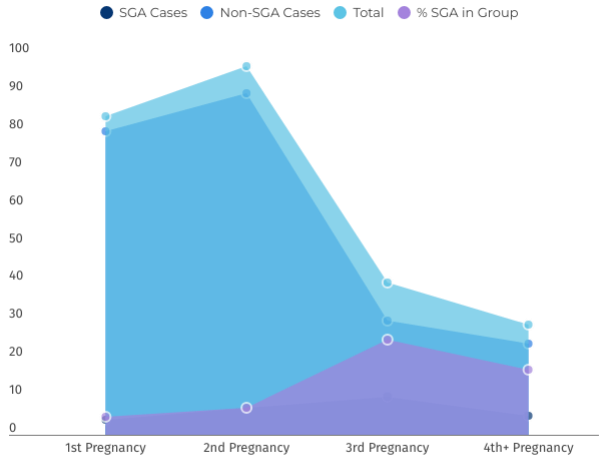

Figure 1 Frequency of SGA and Non-SGA in smokers and non-smokers

DISCUSSION

The findings of this study highlight a 10.4% prevalence of small for gestational age (SGA) foetuses among a cohort of third-trimester pregnant women assessed using the Hadlock method. This prevalence aligns with existing regional estimates, although somewhat lower than global projections, which suggest that over 23 million infants are born SGA annually, particularly in low- and middle-income countries (2,11).

The relatively lower prevalence in our study may be attributed to the specific sociodemographic and geographical characteristics of the study population, along with methodological factors such as prospective data collection and the use of standardized ultrasonography techniques for estimated fetal weight (EFW) determination. The use of the Hadlock method, integrating biometric parameters such as femur length, biparietal diameter, head circumference, and abdominal circumference, ensured precision in classifying SGA and non-SGA fetuses, consistent with its established role in obstetric imaging (4,10).

Our analysis revealed a significant association between maternal tobacco exposure and SGA births, corroborating numerous earlier studies that implicate both active and passive smoking in restricted intrauterine growth (3,14). Nicotine and carbon monoxide are known to induce vasoconstriction and hypoxia, impairing placental perfusion and nutrient delivery to the foetus, which biologically supports the observed growth retardation. The strong statistical significance ($p = 0.000$) in our findings affirms the public health importance of smoking cessation and passive smoke avoidance during pregnancy. Interestingly, while smoking has long been recognized as a modifiable risk factor for low birth weight, our study reinforces its relevance in a South Asian population, where passive smoking due to household exposure remains prevalent.

The study further identified a significant inverse relationship between maternal haemoglobin levels and SGA frequency. Women with lower haemoglobin values exhibited a higher risk of delivering SGA fetuses, a finding in line with previous literature suggesting that maternal anemia reduces the oxygen-carrying capacity of blood, thereby limiting oxygen supply to the fetus (16). In contrast to reports indicating adverse outcomes with very high maternal Hb levels (16), our population predominantly presented with moderate anemia, supporting the hypothesis that both extremes of haemoglobin concentration could potentially compromise fetal development. These findings underline the importance of routine antenatal screening and targeted nutritional interventions to optimize maternal haemoglobin levels during pregnancy.

Contrary to expectations and some previous reports (15), our study did not find a statistically significant association between maternal systolic blood pressure and the occurrence of SGA fetuses. While conditions such as chronic hypertension and preeclampsia have been implicated in intrauterine growth restriction, our exclusion of participants with overt hypertensive disorders might explain this lack of correlation. Furthermore, variations in blood pressure may not fully reflect placental vascular resistance or uteroplacental insufficiency, suggesting that more sensitive biomarkers or longitudinal monitoring may be necessary to capture subtle effects on fetal growth.

Clinically, these findings have significant implications for antenatal care practices in resource-constrained settings. The strong association of SGA with modifiable factors like tobacco exposure and anemia highlights the need for integrated prenatal education, nutritional support, and public health campaigns focusing on maternal well-being. Routine ultrasonography using validated methods such as Hadlock can be a powerful tool for early identification and monitoring of at-risk pregnancies, enabling timely interventions to prevent adverse neonatal outcomes. Furthermore, implementing maternal health policies that promote smoke-free environments and access to iron supplementation could contribute to reducing the SGA burden.

Despite the strengths of prospective design, standardized ultrasound evaluation, and consideration of key maternal risk factors, this study is not without limitations. The sample size, although adequate for initial analysis, limits the power to detect associations with less prevalent or more nuanced factors. The use of convenience sampling may introduce selection bias and limit generalizability beyond the study population. Additionally, reliance on self-reported tobacco exposure may underestimate true exposure levels, and other potential confounders, such as maternal BMI, dietary patterns, and socioeconomic status, were not comprehensively assessed. The study was also limited to a single tertiary care center, reducing external validity to broader populations.

Future research should involve larger, multicenter cohorts with longitudinal follow-up to capture the trajectory of foetal growth and validate risk associations across diverse populations. Studies incorporating biochemical markers of placental function, maternal nutrition, and environmental exposures could deepen understanding of SGA pathophysiology. Additionally, exploration of intervention strategies to mitigate identified risks would be valuable in shaping antenatal care guidelines tailored to regional needs.

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This study contributes valuable insight into the prevalence and maternal determinants of SGA foetuses in a Pakistani clinical context. Tobacco exposure and low haemoglobin levels emerged as significant, modifiable risk factors, whereas systolic blood pressure showed no clear association. These findings emphasize the importance of targeted maternal health interventions and support the integration of ultrasound-based foetal monitoring into routine antenatal care.

CONCLUSION

This study explored the prevalence of small for gestational age (SGA) foetuses using the Hadlock method and examined associated maternal risk factors, revealing a 10.4% frequency of SGA and significant associations with passive tobacco exposure and low maternal haemoglobin levels. These findings emphasize the clinical relevance of integrating ultrasound-based biometric assessments and maternal health screening into routine antenatal care to identify at-risk pregnancies early. The results contribute to a better understanding of preventable factors influencing intrauterine growth restriction and support targeted interventions aimed at improving maternal health to reduce the burden of SGA. Further research is warranted to validate these associations across diverse populations and to assess the effectiveness of preventive strategies in reducing SGA-related perinatal complications.

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