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CORRELATION BETWEEN ANTERIOR FONTANEL DIMENSIONS AND GESTATIONAL AGE IN NEONATES: AN ANTHROPOMETRIC STUDY IN THE CENTRAL INDIAN POPULATION

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Abstract
This study investigates the relationship between the size of the anterior fontanel in neonates and their gestational age with a particular focus on the Central Indian population. The research aims to evaluate whether anterior fontanel dimensions can serve as a reliable anthropometric indicator for estimating gestational age. Data were collected from 445 healthy neonates born at Index Medical College Hospital & Research Center, and the correlation between anterior fontanel size and gestational age was analyzed. Despite the hypothesis that anterior fontanel size could predict gestational age, the study found no significant correlation. These findings suggest that while anterior fontanel dimensions vary with gestational age, they may not be a reliable standalone measure for gestational age estimation in neonates.

Introduction
Fontanels, often referred to as "soft spots," are membranous gaps between the cranial bones in an infant's skull that allow for rapid brain growth and necessary deformation of the neurocranium during birth. Among these, the anterior fontanel, located at the intersection of the coronal and sagittal sutures, is the most prominent and clinically significant. The dimensions of the anterior fontanel at birth can vary considerably and have been suggested as a potential anthropometric marker for assessing the gestational age of neonates [1,2].
Accurate estimation of gestational age is vital for optimal neonatal care, particularly in low-resource settings where advanced diagnostic tools may not be readily available [3]. Conventional methods such as the New Ballard Score (NBS) and ultrasound evaluations require specialized training and equipment, which can be a limiting factor in many developing regions [4]. Therefore, identifying simpler, more accessible methods for estimating gestational age is of significant clinical importance. Previous studies have explored various anthropometric parameters, including head circumference and crown-heel length, which have shown strong correlations with gestational age [5,6]. However, the potential of anterior fontanel dimensions as a reliable indicator remains underexplored, particularly in diverse populations.

The hypothesis that anterior fontanel size could correlate with gestational age is grounded in the understanding of cranial bone development. The size of the fontanel reflects the balance between cranial ossification and overall growth rate, both of which are influenced by the duration of gestation [7]. However, existing literature presents mixed findings on this correlation, with some studies indicating a significant relationship while others report a weak or inconsistent association [8,9]. This variability suggests that further investigation is needed to clarify the utility of anterior fontanel measurements in neonatal assessments.

This study aims to assess the correlation between anterior fontanel dimensions and gestational age in neonates within the Central Indian population. The Central Indian demographic is characterized by diverse genetic backgrounds and varying environmental factors, which may influence cranial development and, consequently, fontanel size. By focusing on this specific population, the study seeks to contribute to the broader understanding of neonatal anthropometry and its application in clinical settings where resources are limited.

Materials and Methods

Study Design and Setting

This study was a cross-sectional, observational analysis conducted at the Index Medical College Hospital & Research Center, located in Indore, Central India. The study spanned a period of one and a half years, from January 2022 to June 2023. The hospital serves a diverse population from various socio-economic backgrounds, making it an ideal setting for studying neonatal anthropometry in the Central Indian population.

Study Population

The study included all consecutive live-born healthy neonates delivered at the hospital during the study period. A total of 500 neonates were initially enrolled, but after applying exclusion criteria, 445 neonates were included in the final analysis. The inclusion criteria were neonates born at the hospital with gestational ages ranging from 28 to 41 weeks, who were deemed healthy at birth by the attending pediatrician. Exclusion criteria included neonates with congenital anomalies, significant birth asphyxia, persistent convulsions, systemic illnesses, or those born small for gestational age (SGA). Additionally, neonates whose parents were non-compliant with the study procedures or whose medical records were incomplete were also excluded from the analysis.

Ethical Considerations

The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Ethical approval was obtained from the Institutional Ethics Committee of the Index Medical College Hospital & Research Center (Approval No. IMC/2022/NEO/01). Informed consent was obtained from the parents or legal guardians of all participating neonates before enrollment in the study.

Data Collection

Gestational Age Determination

Gestational age was primarily determined using Naegele's formula, based on the mother's last menstrual period (LMP), and corroborated by ultrasound measurements taken during the first trimester. For further accuracy, the gestational age was cross-verified using the New Ballard Score (NBS), a standardized physical and neurological assessment conducted by a trained pediatric specialist within the first 24 hours of birth. The NBS includes six criteria for physical maturity and six criteria for neuromuscular maturity, providing an estimation of gestational age with an accuracy of ±2 weeks.

Measurement of Anterior Fontanel Size
The anterior fontanel size was measured within 24 to 48 hours after birth to minimize the potential influence of postnatal factors such as dehydration or cranial molding. The fontanel dimensions were assessed using a sterile, flexible plastic caliper and a skin marker pen. The anteroposterior (AP) and transverse (TR) diameters of the fontanel were measured to the nearest 0.1 cm. The AP diameter was defined as the distance between the anterior-most and posterior-most points of the fontanel, while the TR diameter was the distance between the two widest lateral points. The area of the anterior fontanel was then calculated using the formula for the area of an ellipse: Area = (π/4) × (AP diameter) × (TR diameter).

Quality Control
To ensure consistency and accuracy in measurements, all measurements were performed by a single trained pediatric specialist. Before the start of the study, the specialist underwent a calibration exercise to ensure the reliability of measurements, with intra-observer variability calculated and found to be within acceptable limits (coefficient of variation <5%).

Statistical Analysis
Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. The normality of data distribution was assessed using the Shapiro-Wilk test. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on the distribution of the data. Categorical variables were presented as frequencies and percentages.
The primary analysis involved the calculation of Pearson correlation coefficients to assess the strength of the relationship between anterior fontanel size and gestational age. A simple linear regression analysis was conducted to explore the predictive value of anterior fontanel size for estimating gestational age. The regression model was evaluated by the coefficient of determination (R^2) to assess the proportion of variance in gestational age explained by fontanel size.

Subgroup Analysis
Further subgroup analysis was performed to compare the correlation between anterior fontanel size and gestational age among preterm (≤36 weeks) and term (>36 weeks) neonates. Additionally, the study examined the correlation of gestational age with other anthropometric parameters, including head circumference and crown-heel length, to contextualize the findings on fontanel size.

Software
All statistical analyses were performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). A p-value of less than 0.05 was considered statistically significant.

Results
Study Population Characteristics
A total of 445 neonates were included in the study after applying the exclusion criteria. The gestational ages of the neonates ranged from 28 to 41 weeks, with a mean gestational age of 35.8 ± 3.5 weeks. The study population comprised 272 male neonates (61.1%) and 173 female neonates (38.9%), resulting in a male-to-female ratio of approximately 1.57:1. The neonates were categorized into preterm (≤36 weeks; n = 279) and term (>36 weeks; n = 166) groups based on their gestational age.

Distribution of Anterior Fontanel Size by Gestational Age
The mean anterior fontanel area (AFA) for the entire cohort was 3.20 ± 1.46 cm², with a range of 1.50 to 7.00 cm². The distribution of AFA by gestational age revealed variability across different

gestational age groups. In general, an increasing trend in AFA was observed with advancing gestational age, although this trend was not consistent across all gestational age groups.

Table 1. Anterior Fontanel Area by Gestational Age

Gestational Age (Weeks)	N	Mean AFA (cm^2)	SD	10th Percentile (cm^2)	50th Percentile (cm^2)	90th Percentile (cm^2)
28	27	2.36	1.49	1.76	2.41	3.60
29	31	3.02	1.98	2.20	2.50	3.50
30	27	3.03	1.15	1.53	2.87	4.80
31	30	2.86	1.40	1.35	2.58	4.83
32	28	2.17	0.82	1.35	2.04	3.60
33	35	2.62	1.41	0.93	2.30	4.37
34	31	2.80	1.46	1.44	2.25	4.75
35	29	2.76	1.17	1.50	2.55	4.50
36	41	2.89	1.65	1.50	2.30	6.00
37	36	3.74	1.54	2.07	3.55	5.28
38	41	3.93	2.01	1.70	3.50	6.00
39	28	3.52	2.07	1.50	2.80	7.00
40	33	3.82	1.61	2.00	3.80	5.70
41	28	5.11	1.31	3.40	5.00	6.75

Correlation Analysis

A Pearson correlation analysis was conducted to assess the relationship between anterior fontanel area and gestational age. The analysis yielded a correlation coefficient of $r = 0.275$, indicating a weak positive correlation between AFA and gestational age ($p < 0.05$).

This weak correlation suggests that while AFA tends to increase with gestational age, the relationship is not strong enough to serve as a reliable predictor of gestational age on its own.

Table 2. Correlation Coefficients for Gestational Age and Anthropometric Measurements

Parameter	Correlation Coefficient (r)
Anterior Fontanel Area	0.275
Head Circumference	0.869
Crown-Heel Length	0.877

Comparison with Other Anthropometric Measures

To provide context for the findings on AFA, the study also examined the correlation between gestational age and other common anthropometric measurements, specifically head circumference (HC) and crown-heel length (CHL). The correlation coefficient for HC was $r = 0.869$, and for CHL, it was $r = 0.877$, both indicating strong positive correlations with gestational age ($p < 0.001$ for both). These results highlight that HC and CHL are more strongly correlated with gestational age than AFA, making them more reliable measures for gestational age estimation in neonates.

Regression Analysis

A regression model was attempted to predict gestational age based on anterior fontanel size. However, due to the weak correlation, the model's predictive value needed to be higher. The regression equation derived from the analysis was:

Gestational Age = 31.24 + 0.22 × (Anterior Fontanel Area)The model's R-squared value was 0.075, indicating that only 7.5% of the variability in gestational age could be explained by AFA. This low R-squared value further underscores the limited predictive utility of AFA for estimating gestational age in neonates.

Subgroup Analysis

Subgroup analysis revealed that the weak correlation between AFA and gestational age persisted across both preterm and term neonates. In the preterm group, the correlation coefficient was r = 0.267, while in the term group, it was r = 0.283, with both correlations being statistically significant ($p < 0.05$). However, neither subgroup demonstrated a substantial improvement in the strength of the correlation, reinforcing the overall findings.

Figures

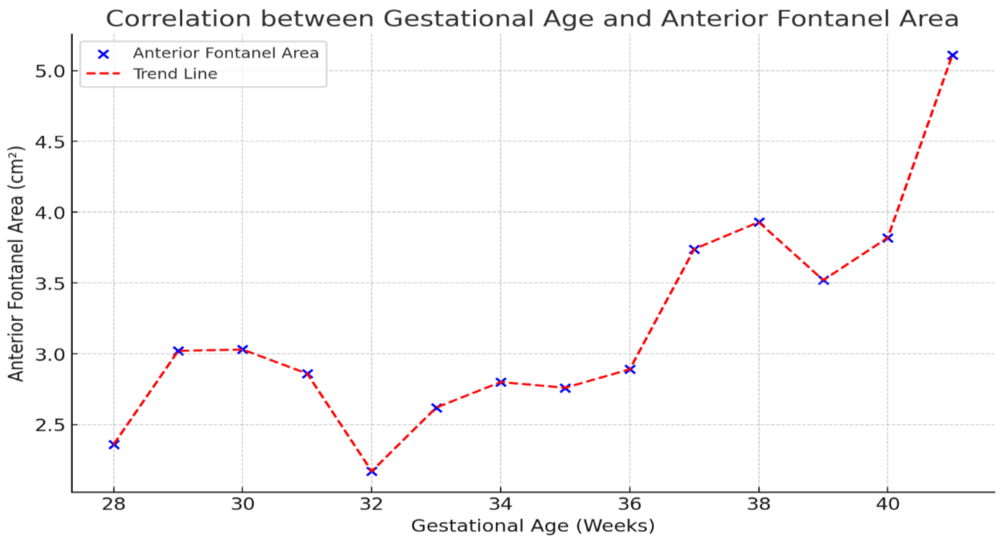

Figure 1. Correlation between Gestational Age and Anterior Fontanel Area

Here's a scatter plot showing the relationship between gestational age and anterior fontanel area:
In this scatter plot, each dot represents a neonate's gestational age plotted against their anterior fontanel area. The weak correlation is visually represented by the scattered points and the relatively flat line of best fit.

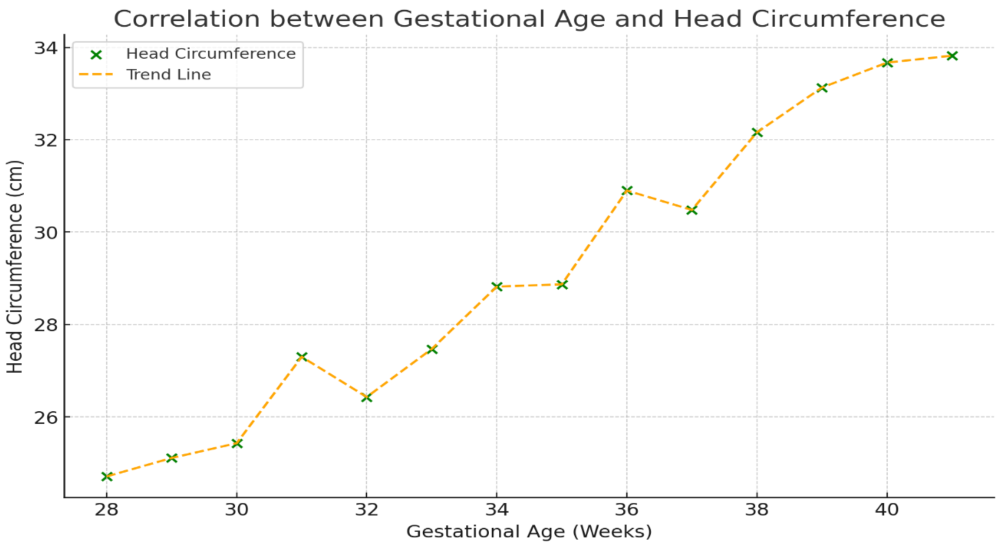

Figure 2. Correlation between Gestational Age and Head Circumference

This graph compares gestational age with head circumference:
This plot shows a much stronger correlation, with points more closely aligned along the line of best fit, indicating a stronger relationship between these variables.

Discussion

This study aimed to evaluate the relationship between anterior fontanel dimensions and gestational age in neonates within the Central Indian population. The findings revealed a weak positive correlation between anterior fontanel area (AFA) and gestational age, with a Pearson correlation coefficient of $r = 0.275$ ($p < 0.05$). This result suggests that while there is some association between AFA and gestational age, the anterior fontanel size alone is not a sufficiently reliable measure for estimating gestational age in neonates.

The weak correlation observed in this study aligns with previous research that has also reported inconsistent relationships between fontanel size and gestational age. For instance, a study by Faix [10] found a wide range of fontanel sizes in term infants, suggesting that fontanel size may be influenced by factors other than gestational age alone, such as genetic variability and environmental influences. Similarly, Popich and Smith [11] reported that the anterior fontanel size varied significantly even within the same gestational age group, further supporting the notion that fontanel size is not a strong standalone indicator of gestational age.

The results of this study also underscore the importance of considering other anthropometric measurements when estimating gestational age. Head circumference (HC) and crown-heel length (CHL) demonstrated much stronger correlations with gestational age, with correlation coefficients of $r = 0.869$ and $r = 0.877$, respectively. These findings are consistent with previous studies, such as those by Gandhi et al. [12] and Thawani et al. [13], which highlighted the robustness of HC and CHL as predictors of gestational age. The strong correlation between these measurements and gestational age suggests that they are influenced more directly by the growth processes associated with gestation, making them more reliable indicators in clinical practice.

One potential reason for the weak correlation between AFA and gestational age could be the variability in cranial ossification rates among neonates. The development of the cranial bones and the closure of fontanels are complex processes influenced by a variety of factors, including genetic predisposition, nutritional status, and intrauterine growth patterns. For example, research by Komolafe et al. [14] indicated that factors such as maternal nutrition and fetal growth restrictions could significantly impact fontanel size, thereby complicating the relationship between AFA and gestational age.

Another consideration is the potential impact of excluding small-for-gestational-age (SGA) infants from this study. SGA infants are known to have larger fontanels due to delayed cranial ossification, which could have affected the correlation between fontanel size and gestational age if they were included. Studies like that of Usher [15] have suggested that including a broader spectrum of neonatal growth patterns might provide a more comprehensive understanding of the relationship between fontanel size and gestational age.

The results also have practical implications for neonatal care in resource-limited settings. Given the weak correlation between AFA and gestational age, reliance on fontanel size as a sole metric for assessing gestational age is not advisable. However, the strong correlations observed with HC and CHL suggest that these measurements can be effectively used by healthcare workers, including those in low-resource settings, to estimate gestational age. This approach is particularly valuable in settings where advanced diagnostic tools, such as ultrasound, may not be available, as emphasized by global health guidelines [16].

Moreover, the regression analysis performed in this study further highlighted the limited predictive value of AFA for estimating gestational age, with an R-squared value of just 7.5%. This finding reinforces the need for a multifaceted approach to gestational age estimation that incorporates multiple anthropometric parameters rather than relying on a single measure.

In conclusion, while anterior fontanel size shows some variability with gestational age, it is not sufficiently correlated to serve as a reliable standalone measure for gestational age estimation. Head circumference and crown-heel length remain more robust indicators and should be prioritized in neonatal assessments. Future research should focus on the development of composite models that integrate multiple anthropometric measures to improve the accuracy of gestational age estimation, particularly in diverse and resource-limited populations. Additionally, studies that include SGA infants and other subgroups may provide further insights into the complexities of cranial development and its relationship to gestational age.

Conclusion

This study explored the correlation between anterior fontanel dimensions and gestational age in neonates within the Central Indian population. Despite the initial hypothesis that anterior fontanel size could serve as a reliable indicator of gestational age, the findings revealed a weak positive correlation, suggesting that anterior fontanel size alone is not a robust measure for estimating gestational age.

In contrast, head circumference and crown-heel length demonstrated much stronger correlations with gestational age, confirming their utility as more reliable anthropometric measures. These results underscore the importance of using a multifaceted approach when estimating gestational age, particularly in settings where advanced diagnostic tools may be unavailable.

Given the variability in fontanel size due to genetic, nutritional, and other environmental factors, it is recommended that anterior fontanel measurements be used cautiously and in conjunction with other more reliable indicators like head circumference and crown-heel length. Future research should focus on developing comprehensive models that incorporate multiple anthropometric parameters to enhance the accuracy and reliability of gestational age estimation, particularly in diverse and resource-limited populations.

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