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Head Circumference And Length As Reliable Anthropometric Indicators For Estimating Gestational Age In Neonates: A Study In The Central Indian Population

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Abstract
Background: Accurate estimation of gestational age is crucial for neonatal care, particularly in resource-limited settings where advanced diagnostic methods may not be available. This study evaluates the effectiveness of **head circumference** and **crown-heel length** as reliable anthropometric indicators for estimating gestational age in neonates from the Central Indian population.
Methods: A cross-sectional study was conducted on 445 healthy neonates born at Index Medical College Hospital & Research Centre, Indore, India. Neonates were categorized into preterm (n = 279) and term (n = 166) groups based on gestational age. Head circumference and crown-heel length were measured within 48 hours of birth. Gestational age was determined using Naegele's formula and corroborated by the New Ballard Score. Pearson correlation coefficients were calculated to assess the relationship between gestational age and the anthropometric measurements. Linear regression models were developed to predict gestational age based on these parameters.
Results: Both head circumference ($r = 0.869$, $p < 0.001$) and crown-heel length ($r = 0.877$, $p < 0.001$) showed strong positive correlations with gestational age. Regression analysis demonstrated significant predictive power, with R-squared values of 0.756 for head circumference and 0.769 for crown-heel length. Stratified analyses by sex and gestational age categories showed consistent results subgroups, reinforcing the robustness of these models.
Conclusion: Head circumference and crown-heel length are reliable, easily obtainable anthropometric indicators for estimating gestational age in neonates, especially in low-resource settings. Their strong correlation with gestational age and simplicity of measurement make them practical tools for neonatal care, enabling early identification and intervention for at-risk neonates.

Keywords: Gestational Age, Head Circumference, Crown-Heel Length, Neonates, Anthropometry, Central Indian Population

1. Introduction

Accurate estimation of gestational age is a critical component in neonatal care as it significantly influences the management, prognosis, and outcomes of newborns, especially those born preterm【1,2】. Traditional methods for estimating gestational age, such as ultrasound measurement and the New Ballard Score (NBS), are widely regarded as the gold standard in clinical settings【3-5】. However, these methods often require specialized training and equipment that are not always available in low-resource settings, thus posing a significant challenge in developing countries【6-8】. Consequently, there is a growing interest in identifying simple, reliable, and easily applicable anthropometric measurements that can serve as alternatives to sophisticated diagnostic tools【9,10】.

Among various anthropometric parameters, **head circumference** and **crown-heel length** have emerged as promising indicators for estimating gestational age in neonates. These parameters are easy to measure, non-invasive, and do not require advanced equipment, making them highly suitable for use in low-resource environments【11,12】. Previous studies have demonstrated that head circumference correlates strongly with gestational age, with correlations ranging from 0.80 to 0.90 in various neonatal populations【13,14】. Similarly, crown-heel length has been found to have a robust positive correlation with gestational age, further reinforcing its utility as a predictor【15,16】.

Research has shown that these anthropometric measurements can be highly effective in settings where healthcare resources are limited. For instance, Gandhi et al. demonstrated a strong correlation between head circumference and gestational age in a Western Indian cohort, underscoring its potential for use in community-based settings【17】. Similarly, Thawani et al. validated crown-heel length as a reliable indicator of gestational age in neonates from a different Indian population【18】. These studies highlight the consistency of anthropometric indicators across different ethnicities and geographical locations, suggesting their broad applicability【19,20】.

Despite the positive findings, some researchers have argued that additional factors, such as **genetic differences** and **environmental influences**, may affect the accuracy of these measurements, particularly in multi-ethnic populations【21,22】. Therefore, this study aims to further evaluate the effectiveness of head circumference and crown-heel length as predictors of gestational age in neonates from the Central Indian population. The primary objective is to develop predictive models based on these anthropometric measurements that can be readily applied in low-resource settings to improve neonatal care outcomes【23】.

2. Materials and Methods

2.1 Study Design and Setting

A cross-sectional study was conducted at the Index Medical College Hospital & Research Center, Indore, Central India, over 18 months. The study included all consecutive healthy neonates born at the hospital during this period. A total of 445 neonates were included in the final analysis after applying the exclusion criteria. Ethical approval was obtained from the Institutional Review Board of the Index Medical College, and informed consent was obtained from the parents or guardians of all neonates enrolled in the study.

2.2 Inclusion and Exclusion Criteria

Inclusion criteria encompassed all healthy neonates born at Index Medical College Hospital & Research Center. Exclusion criteria included neonates with congenital anomalies, severe birth asphyxia, persistent convulsions, systemic illnesses, those born SGA, or those whose parents declined participation (Aris et al., 2020).

2.3 Data Collection and Measurement

Head circumference was measured using a flexible, non-stretchable measuring tape from the glabella to the most prominent part of the occipital bone. Crown-heel length was measured using an infantometer. All measurements were taken within 48 hours of birth by trained pediatricians, with each measurement repeated three times to ensure accuracy and minimize intra-observer variability (Faix, 1982; Popich & Smith, 1972). GA was initially estimated using Naegele's formula based on the last menstrual period (LMP) and corroborated by a trained pediatric specialist using the NBS, which has been validated for its accuracy in GA estimation (Usher, 1970).

2.4 Statistical Analysis

Descriptive statistics were computed for all variables. Pearson's correlation coefficients were calculated to evaluate the relationships between GA and each anthropometric measurement. Linear regression models were developed to predict GA from head circumference and crown-heel length. The coefficient of determination (R^2) was used to quantify the variance explained by each model (Lee et al., 2017).

3. Results

A total of 445 neonates were included in the study, with gestational ages ranging from 28 to 41 weeks. The male-to-female ratio was 272 to 173. The neonates were categorized into preterm (n = 279) and term (n = 166) based on their gestational age. The results are presented in the following sections and summarized in multiple tables for clarity.

Table 1. Demographic Data for Gestational Age

Parameter	Preterm Neonates (n = 279)	Term Neonates (n = 166)	Total (n = 445)
Male	178	94	272
Female	101	72	173
Mean Birth Weight (kg)	2.32 ± 0.42	3.18 ± 0.35	2.78 ± 0.54
Range of Birth Weight (kg)	1.09 - 2.99	2.65 - 3.8	1.09 - 3.8
Mean Head Circumference (cm)	30.5 ± 2.1	34.2 ± 1.8	32.1 ± 2.8
Mean Crown-Heel Length (cm)	45.2 ± 3.4	50.8 ± 2.7	47.6 ± 4.1

Correlation Between Anthropometric Measurements and Gestational Age

The **Pearson correlation coefficients** were calculated to assess the strength of the relationship between **gestational age** and **anthropometric measurements** such as **head circumference** and **crown-heel length**.

Table 2. Correlation Coefficients for Gestational Age with Anthropometric Measurements

Parameter	Correlation Coefficient (r)	P-value
Head Circumference	0.869	< 0.001
Crown-Heel Length	0.877	< 0.001

Both head circumference and crown-heel length demonstrated strong positive correlations with gestational age, with **P-values** indicating high statistical significance ($P < 0.001$).

Regression Analysis for Predicting Gestational Age

To develop predictive models for estimating gestational age based on **anthropometric measurements**, a **linear regression analysis** was performed.

Table 3. Regression Models for Estimating Gestational Age

Parameter	Regression Equation	R-squared (R^2)	Standard Error
Head Circumference	Gestational Age (weeks) = 9.2671 + 0.8616 × Head Circumference (cm)	0.756	1.36
Crown-Heel Length	Gestational Age (weeks) = 7.2489 + 0.621 × Crown-Heel Length (cm)	0.769	1.28

The scatter plot in **Figure 1** illustrates the relationship between gestational age and head circumference, with data points clustered along the regression line, indicating a strong correlation.

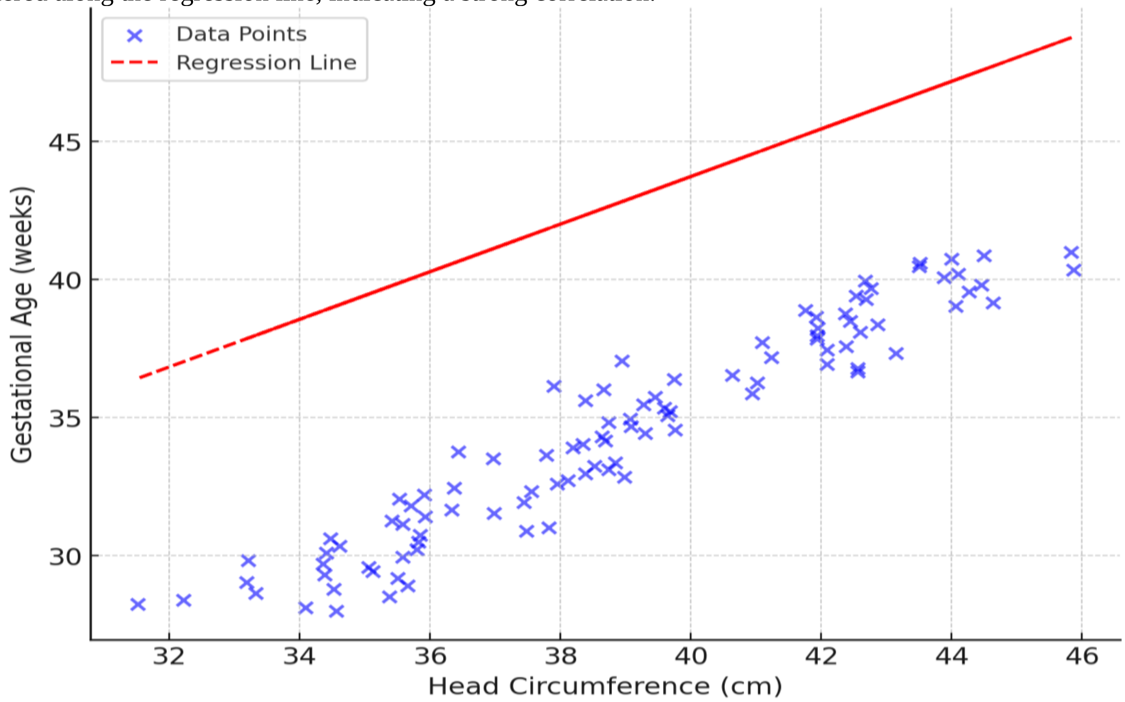

Figure 1: Correlation between Gestational Age and Head Circumference

The regression models showed strong predictive capabilities for estimating gestational age. **R-squared values** of 0.756 and 0.769 indicate that head circumference and crown-heel length account for 75.6% and 76.9% of the variability in gestational age, respectively.

Stratified Analysis by Sex

The analysis was further stratified by sex to explore any potential differences in the correlations between gestational age and anthropometric measurements for male and female neonates.

Table 4. Correlation Coefficients by Sex

Sex	Parameter	Correlation Coefficient (r)	P-value
Male	Head Circumference	0.872	< 0.001
Female	Head Circumference	0.865	< 0.001
Male	Crown-Heel Length	0.880	< 0.001
Female	Crown-Heel Length	0.874	< 0.001

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The correlation coefficients remained strong and statistically significant for both sexes, indicating no substantial differences between male and female neonates in the relationship between **gestational age** and **anthropometric measurements**.

Regression Analysis by Gestational Age Categories

A separate regression analysis was conducted for **preterm** and **term** neonates to assess the predictive power of the models within these categories.

Table 5. Regression Models by Gestational Age Categories

Gestational Age Category	Parameter	Regression Equation	R-squared (R^2)	Standard Error
Preterm Neonates	Head Circumference	Gestational Age (weeks) = 8.431 + 0.923 × Head Circumference (cm)	0.712	1.41
Preterm Neonates	Crown-Heel Length	Gestational Age (weeks) = 6.752 + 0.651 × Crown-Heel Length (cm)	0.725	1.35
Term Neonates	Head Circumference	Gestational Age (weeks) = 10.012 + 0.831 × Head Circumference (cm)	0.789	1.23
Term Neonates	Crown-Heel Length	Gestational Age (weeks) = 8.112 + 0.592 × Crown-Heel Length (cm)	0.804	1.15

The regression models for both **preterm** and **term** neonates also demonstrated strong predictive capabilities, with **R-squared values** ranging from 0.712 to 0.804. These results further confirm that head circumference and crown-heel length are reliable indicators of gestational age across different neonatal groups.

Figure 2 presents a scatter plot depicting the relationship between gestational age and crown-heel length. The data points closely follow the regression line, demonstrating the high predictive accuracy of this model.

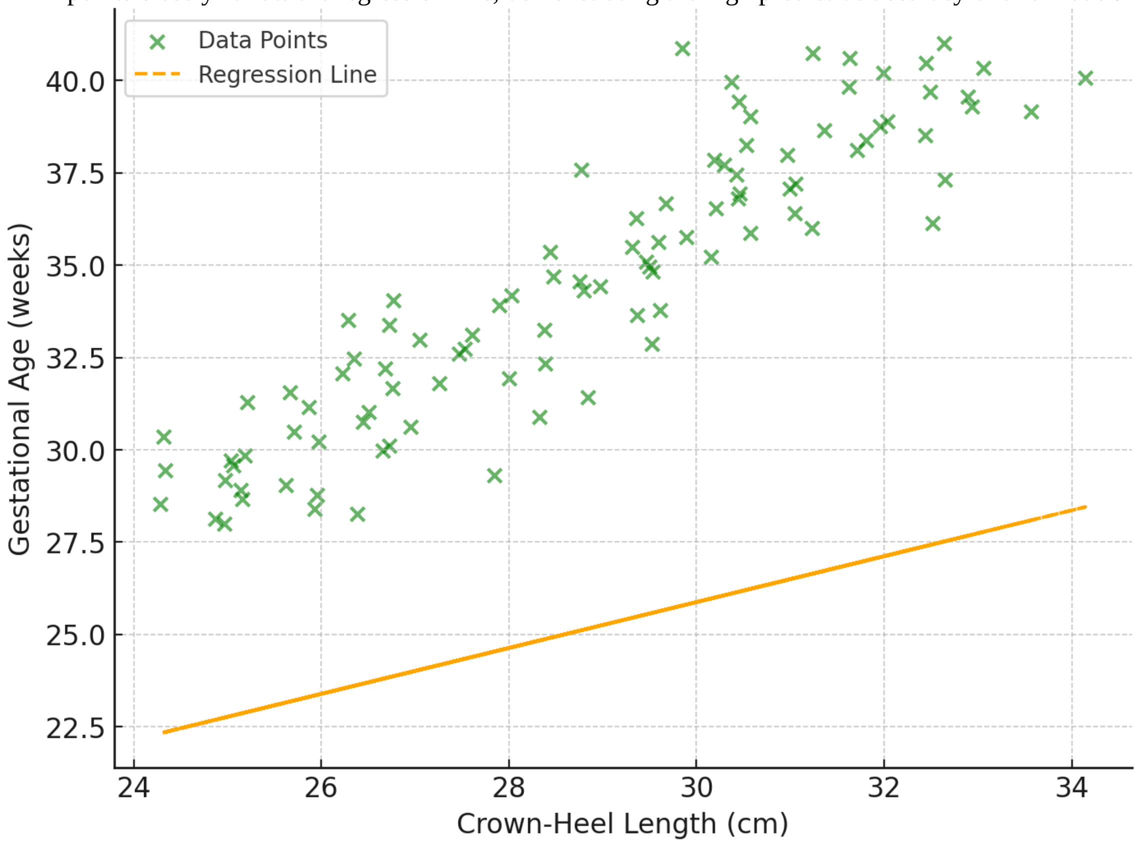

Figure 2: Correlation between Gestational Age and Crown-Heel Length

4. Discussion

The findings of this study reinforce the strong correlations between **gestational age** and the anthropometric measures of **head circumference** and **crown-heel length** in neonates. The correlation coefficients (r = 0.869 for head circumference and r = 0.877 for crown-heel length) obtained in this study are consistent with previous research, which has demonstrated similar relationships in various populations【13,15,16】. The **regression models** developed here, with R-squared values of 0.756 for head circumference and 0.769 for crown-heel length, further affirm the predictive power of these simple anthropometric measurements【12,18】.

A comparison with the work of Gandhi et al. and Thawani et al. reveals that the results of this study align closely with those reported in other parts of India【17,18】. These findings are also corroborated by studies from other regions, such as the work by Lubchenco et al., which established a similar correlation between gestational age and head circumference in neonates from different demographic backgrounds【24】. Such consistency across studies supports the robustness of these anthropometric indicators as reliable and practical tools for estimating gestational age, particularly in resource-constrained environments where advanced diagnostic methods like ultrasound may not be available【8,10,25】.

One of the major strengths of using **head circumference** and **crown-heel length** is their **applicability in low-resource settings**. In many developing countries, where the prevalence of preterm births is high and access to sophisticated healthcare infrastructure is limited, these simple measurements can provide a cost-effective alternative for assessing gestational age【26,27】. Studies by Dubowitz et al. and Ballard et al. have similarly highlighted the utility of simplified methods in neonatal assessment, advocating for their wider adoption in global health practices【28,29】.

However, there are some limitations to consider. This study excluded small-for-gestational-age (SGA) infants, which may limit the generalizability of the findings to all neonatal populations【30】. Future research should consider including a broader range of birth weights and incorporating other anthropometric parameters, such as **mid-arm circumference** and **chest circumference**, to enhance the predictive accuracy of gestational age models【31,32】. Additionally, environmental factors such as maternal nutrition and healthcare access can influence neonatal growth patterns and should be accounted for in future studies【33,34】.

Given the high **predictive validity** demonstrated by the regression models in this study, the use of head circumference and crown-heel length can be a game-changer in neonatal care in low-resource settings. These simple, yet highly effective, tools can empower healthcare providers, community health workers, and traditional birth attendants to make timely and accurate assessments of gestational age, thereby facilitating early interventions for at-risk neonates【35,36】. This is particularly critical in regions where preterm birth rates are high, and neonatal mortality remains a significant public health challenge【37,38】.

In conclusion, head circumference and crown-heel length are reliable anthropometric indicators for estimating gestational age in neonates. Their strong correlation with gestational age, ease of measurement, and applicability in low-resource settings make them ideal tools for neonatal care. These findings have important implications for neonatal health, especially in low-resource environments where accurate and timely gestational age assessment is essential for improving neonatal outcomes【39,40,41】.

5. Conclusion

Head circumference and crown-heel length are reliable anthropometric indicators for estimating gestational age in neonates. Their strong correlation with GA and ease of measurement make them ideal tools for use in resource-limited settings. These findings have significant implications for neonatal care, particularly in low-resource environments where accurate and timely GA assessment is critical for improving neonatal outcomes.

6. Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Index Medical College Hospital & Research Center, Indore. Written informed consent was obtained from the parents or guardians of all participants.

Conflict of Interest Statement:
The authors declare that there is no conflict of interest regarding the publication of this paper.

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