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Original Research Article

Correlation between neonatal foot length and gestational age: a tertiary care hospital-based study

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ABSTRACT

Background: Accurate gestational age (GA) assessment is crucial for neonatal care, particularly in resource-limited settings where ultrasonography and trained personnel may be unavailable. Foot length measurement offers a simple, low-cost alternative for identifying preterm newborns who require specialized care.
Methods: A cross-sectional study was conducted at Mother Hospital, Thrissur, Kerala, from December 2022 to December 2023. Two hundred healthy newborns above 34 weeks gestation were included. Foot length was measured using sliding calipers with millimeter accuracy. Gestational age was calculated from the last menstrual period. Other anthropometric parameters including head circumference, crown-heel length and birth weight were also measured. Pearson correlation coefficient and linear regression analysis were performed to determine the relationship between foot length and gestational age.
Results: Of 200 neonates studied, 59% were male and 41% female; 77% were term and 23% preterm. Mean foot length was significantly higher in term babies (7.89±0.29 cm) compared to preterm babies (7.23±0.22 cm). Foot length showed a strong positive correlation with gestational age ($r=0.76$, $p<0.001$), which was superior to correlations with head circumference ($r=0.37$), crown-heel length ($r=0.62$) and birth weight ($r=0.69$). The regression equation derived was: gestational Age=15.614+2.814×foot length. ROC curve analysis demonstrated excellent discriminatory ability (AUC=0.945) with an optimal cut-off of 7.55 cm (sensitivity 91.3%, specificity 91.6%).
Conclusions: Neonatal foot length is a reliable, simple and accurate proxy measure for gestational age assessment. This measurement can be effectively utilized by trained or untrained personnel in resource-poor settings for early identification of preterm newborns requiring specialized care.

Keywords: Foot length, Gestational age, Preterm, Newborn, Anthropometry, Low birth weight

INTRODUCTION

Infant mortality rate remains a critical indicator of a country's health status. While global under-five mortality has declined substantially, neonatal deaths continue to account for approximately 64% of all infant deaths, with most occurring in the first week of life.[1-3] The three leading causes of neonatal mortality prematurity, infections, and intrapartum-related events are eminently preventable with timely identification and intervention.[2-4] Preterm birth, defined by the World Health Organization as births before 37 completed weeks of gestation, affects an estimated 13.4 million babies annually.[5] Preterm birth complications cause approximately 900,000 deaths yearly among children under five years, with three-quarters being preventable through the cost-effective interventions.[5-7] Early identification of preterm newborns within 48 hours of birth is crucial for implementing life-

saving interventions such as kangaroo mother care, early breastfeeding support and infection prevention.[8,9] Gestational age (GA) assessment is fundamental for appropriate neonatal care. While Naegele's formula and ultrasonography are standard methods, their application is limited in low-resource settings due to low literacy levels, unavailability of equipment and lack of trained personnel.[10] Clinical assessment tools like the New Ballard score, though valid and reliable, require skilled examiners and may be less accurate in critically ill neonates.[11,12] Anthropometric measurements offer practical alternatives for gestational age assessment. Several studies have demonstrated strong correlations between various body parameters and the gestational age.[13-17] Among these, foot length has emerged as a particularly promising measure due to its ease of measurement, minimal equipment requirements and reliability even in critically ill infants who require minimal handling.[18-27] This study aims to establish the correlation between neonatal foot length and gestational age, and to determine whether foot length can serve as a simple, reliable predictor of gestational age that can be utilized by both trained and untrained personnel in resource-limited settings.

METHODS

Study design and setting

This institutional-based cross-sectional study was conducted in the Department of Paediatrics at Mother Hospital, Thrissur, Kerala a tertiary care hospital serving a tier-2 city in India.

Study population and sample size

All neonates delivered at Mother Hospital above 34 weeks gestation were eligible for inclusion. Sample size was calculated using the formula based on correlation coefficients from previous studies, yielding a sample size of 200 neonates.

Study period

Data collection was conducted from December 2022 to December 2023.

Inclusion and exclusion criteria

Inclusion criteria

All healthy newborns above 34 weeks gestation delivered at Mother Hospital within 24 hours of life were included in the study.

Exclusion criteria

Neonates with skeletal deformities of the foot (such as congenital talipes equinovarus, rocker-bottom foot) that would hinder accurate anthropometric measurement were excluded.

Measurement procedures

Gestational age

Calculated from the last menstrual period (LMP) using Naegele's formula.

Foot length

Measured using sliding calipers with millimeter accuracy. Measurements were taken from the posterior-most prominence of the heel to the tip of the longest toe of the right foot. The ventral surface of the foot was straightened using gentle pressure during measurement. Length was documented in centimeters.



Figure 1: Measurement of foot length using sliding caliper.

Demonstration of proper technique for measuring neonatal foot length from posterior heel prominence to tip of longest toe using sliding calipers with millimeter accuracy. The ventral surface is straightened with gentle pressure.

Head circumference

Measured using a flexible, non-stretchable fiber measuring tape encircling the occipital prominence posteriorly, just above the ear lobes laterally, just above the supraorbital ridge anteriorly. Measurement accuracy was nearest millimeter, documented in centimeters.

Crown-heel length

Measured using an infant meter with assistant support. The neonate's lower limbs were fully straightened before measurement, documented in centimeters.

Birth weight

Measured using an electronic weighing scale with ±5 gm accuracy. All clothing was removed before weighing, documented in grams.

Statistical analysis

Data were entered in Microsoft Excel 2016 and analyzed using SPSS version 24. Continuous variables were summarized using means and standard deviations with 95% confidence intervals. Categorical variables were presented as frequencies and percentages. Pearson correlation coefficient was calculated to assess relationships between variables. Linear regression analysis was performed to develop predictive equations. Receiver operating characteristic (ROC) curve analysis was conducted to determine optimal cut-off values. A p value <0.05 was considered statistically significant.

Ethical considerations

The study was approved by the institutional ethical committee. Written informed consent was obtained from parents of all participants. No additional financial burden or interventions beyond routine anthropometric measurements were required. The four universal ethical principles in biomedical research were adhered to throughout the study.

RESULTS

Demographic characteristics

Two hundred neonates were enrolled in the study. Male neonates comprised 59% (n=118) and females 41% (n=82). Based on maturity, 154 (77%) were term babies and 46 (23%) were preterm; no post-term babies were included. Birth weight distribution showed 39 (19.5%) low birth weight (<2.5 kg), 142 (71%) normal birth weight (2.5-3.5 kg), and 19 (9.6%) macrosomic (>3.5 kg) neonates.

Foot length measurements

Mean foot length in male babies was 7.68±0.40 cm (range 6.7-8.3 cm, 95% CI:7.61-7.75) compared to 7.81±0.36 cm in females (range 6.9-8.4 cm, 95% CI: 7.73-7.89). Term babies demonstrated significantly greater mean foot length (7.89±0.29 cm, 95% CI:7.84-7.93) compared to preterm babies (7.23±0.22 cm, 95% CI:7.16-7.29). Foot length showed significant variation across birth weight categories (p<0.001): babies <2.5 kg had mean foot length of 7.27±0.26 cm, those between 2.5-3.5 kg measured 7.82±0.31 cm, and babies >3.5 kg measured 8.05±0.35 cm.

Other anthropometric parameters

Mean birthweight was 3.03 kg in term babies with standard deviation of 0.41 compared to 2.37 kg with standard deviation of 0.52 in preterm babies. Mean head circumference was 33.63±1.08 cm in term babies versus 32.8±1.44 cm in preterm babies. Mean crown-heel length was 48.94±1.53 cm in term babies compared to 46.75±2.48 cm in preterm babies.

Table 1: Sex distribution of babies.

Sex	Number (N)	Percentage (%)
Male	118	59
Female	82	41
Total	200	100

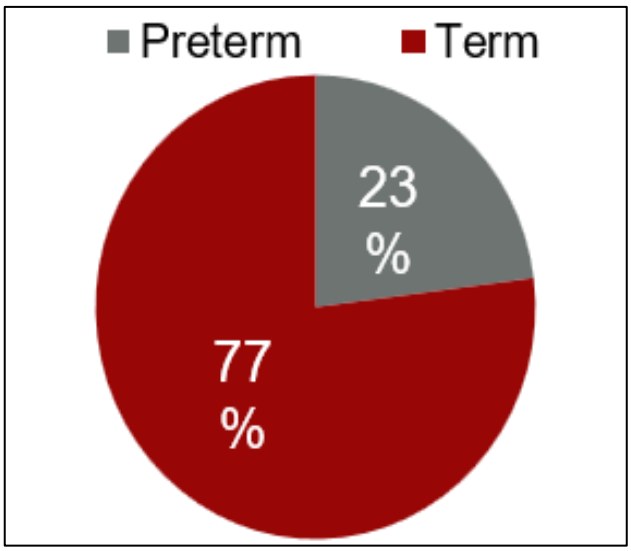


Figure 2: Classification of newborns according to maturity.

Correlation analysis

Foot length demonstrated the strongest correlation with gestational age (r=0.76, p<0.001, r^2=0.577), indicating that 57.7% of gestational age variation could be explained by foot length. This correlation was superior to birth weight (r=0.69, p<0.001), crown-heel length (r=0.62, p<0.001) and head circumference (r=0.37, p<0.001). y =15.61+ 2.81x, r^2 linear=0.577.

Scatter plot with regression line showing strong positive correlation (r=0.76, p<0.001, r^2=0.577) between gestational age (x-axis, weeks) and foot length (y-axis, cm). Equation: GA=15.61+2.81×FL.

Regression analysis

Linear regression yielded the equation: Gestational Age (weeks)=15.614+2.814×foot length (cm). The model showed statistical significance (t=19.569, p<0.001) with standardized coefficient beta=0.76.

Table 2: Foot length by sex distribution.

Sex	N	Mean (cm)	SD	Minimum	Maximum	95% CI
Male	118	7.68	0.40	6.7	8.3	7.61-7.75
Female	82	7.81	0.36	6.9	8.4	7.73-7.89

Table 3: Comparison of anthropometric parameters between term and preterm neonates.

Parameters	Maturity	N	Mean	SD	Minimum	Maximum	95% CI
Foot length (cm)	Term	154	7.89	0.29	6.9	8.4	7.84-7.93
	Preterm	46	7.23	0.22	6.7	7.8	7.16-7.29
Birth weight (kg)	Term	154	3.03	0.41	1.81	4.2	2.96-3.09
	Preterm	46	2.37	0.52	1.47	3.6	2.22-2.52
Head circumference (cm)	Term	154	33.63	1.08	31.5	37	33.46-33.81
	Preterm	46	32.8	1.44	29	35	32.38-33.23
Crown-heel length (cm)	Term	154	48.94	1.53	42	53	48.70-49.19
	Preterm	46	46.75	2.48	40	51	46.01-47.49

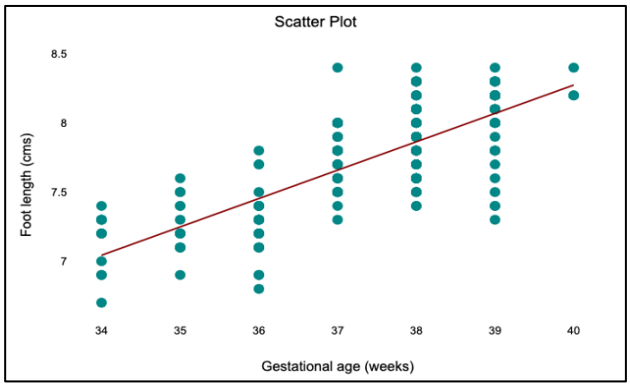


Figure 3: Scatter diagram correlation between GA and foot length.

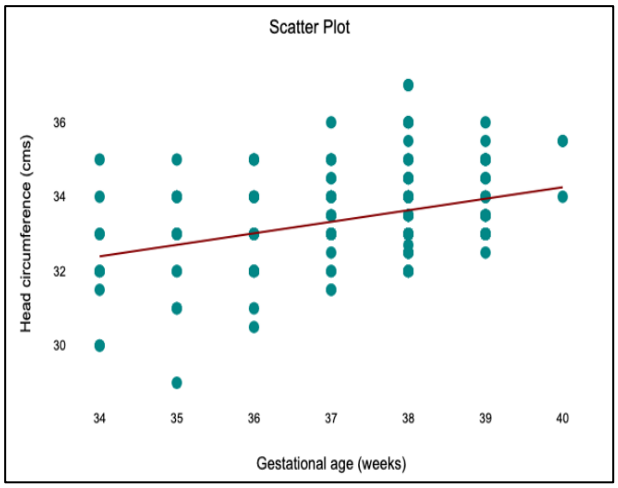


Figure 4: Scatter diagram correlation between GA and head circumference.

Scatter plot demonstrating moderate positive correlation (r=0.37, p<0.001) between gestational age and head circumference. y=22.85+0.43x, r^2 linear=0.136.

ROC curve analysis

It demonstrated excellent discriminatory ability of foot length for identifying preterm births, with area under curve (AUC) of 0.945 (95% CI: 0.904-0.987, p<0.001). The optimal cut-off value of 7.55 cm provided sensitivity of 91.3% and specificity of 91.6%, with positive predictive value of 79.2% and negative predictive value of 97.2%.

Operating characteristic (ROC) curve analysis

ROC curve demonstrating excellent discriminatory ability of foot length for identifying preterm births. Area under curve (AUC)=0.945 (95% CI:0.904-0.987, p<0.001). The diagonal reference line represents no discrimination. Optimal cut-off point of 7.55cm provides sensitivity of 91.3% and specificity of 91.6%.

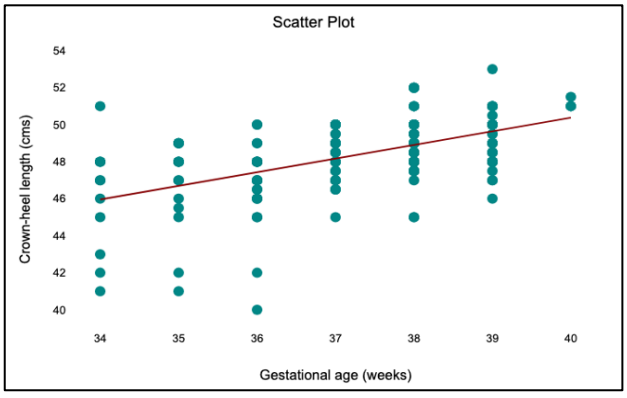


Figure 5: Scatter diagram correlation between GA and crown-heel length.

Scatter plot showing positive correlation (r=0.62, p<0.001) between gestational age and crown-heel length. y=19+0.38x, r^2 linear=0.280.

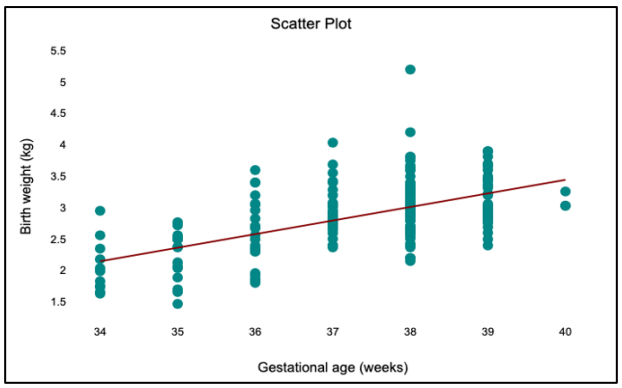


Figure 6: Scatter diagram correlation between GA and birth weight.

Scatter plot illustrating positive correlation (r=0.69, p<0.001) between gestational age and birth weight. Y=32.95+1.54X, r^2 linear =0.336.

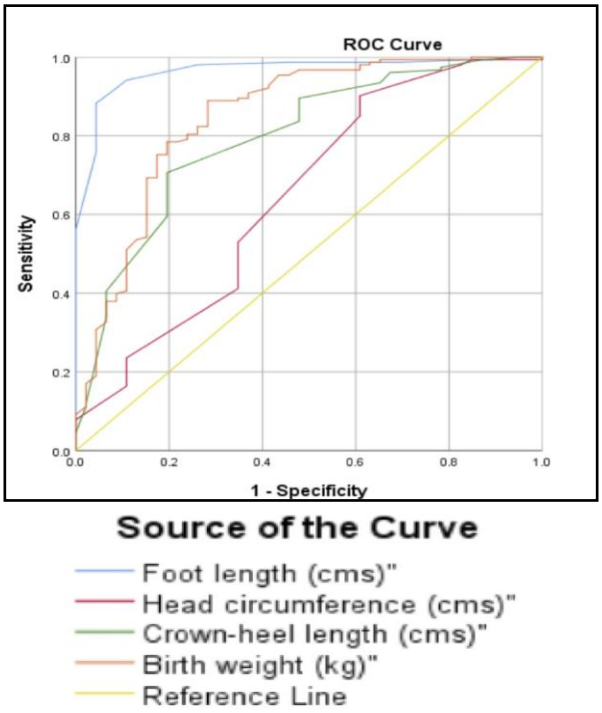


Figure 7: Receiver operating characteristic (ROC) curve analysis.

DISCUSSION

This study establishes foot length as a highly reliable anthropometric parameter for gestational age assessment in newborns. The strong positive correlation (r=0.76) between foot length and gestational age demonstrates superior predictive value compared to other commonly measured parameters including birth weight, crown-heel length and head circumference.

Our findings align with previous research by Daga et al, who established foot length as a practical screening tool for identifying at-risk newborns in resource-limited settings.[7,8,27]

The correlation coefficient in our study is comparable to that reported in various studies showing strong correlations between foot length and body size indices, particularly in premature infants and critically ill neonates. The regression equation derived in our study (GA=15.614 +2.814×FL) provides a practical tool for estimating gestational age from foot length measurements. This formula can be readily applied by healthcare workers at various levels, from trained pediatricians to community health workers and traditional birth attendants, as demonstrated in field implementation studies.[8,27] The ROC curve analysis revealing an AUC of 0.945 confirms excellent diagnostic accuracy. The optimal cut-off of 7.55 cm, with balanced sensitivity (91.3%) and specificity (91.6%), provides a practical threshold for identifying preterm newborns requiring specialized care. This aligns with findings by Dagnew et al who reported high sensitivity and specificity of foot length for preterm identification in rural Ethiopian settings.[29]

Several factors contribute to foot length's utility as a screening tool: measurement requires minimal, inexpensive equipment; the technique is simple and reproducible with minimal training; it can be measured in critically ill infants with minimal handling; and it is not affected by edema or molding that may influence other measurements.[18,19] Studies by Platt et al, Mercer et al and Goldstein et al, demonstrated high correlation between ultrasonic and clinical foot length measurements.[18-20] Clinical implications are significant for low-resource settings, enabling early identification of preterm newborns for timely interventions like kangaroo mother care and infection prevention.[9,30]

Anthropometric studies by Sharma et al, Bhatia et al and Bhat et al evaluated various parameters for birth weight assessment.[15-17] Ultrasonographic studies by Kustermann et al, Kumar et al, Hern et al and Mhaskar et al established correlations between fetal measurements and gestational age.[22-25] Future research should focus on developing simplified measurement tools for community use and evaluating implementation strategies in diverse populations.[29,30]

Limitations

First, being a single-center investigation conducted at a tertiary care facility, the findings may not fully generalize to community-based births or different socioeconomic settings. Second, the explicit exclusion of extremely preterm infants under 34 weeks gestation prevents the validation of our diagnostic thresholds within this highly critical subpopulation. Finally, neonates with congenital structural or skeletal foot deformities were excluded, meaning these specific cut-off values cannot be applied to newborns with localized musculoskeletal anomalies.

CONCLUSION

Neonatal foot length emerges as a simple, reliable, accurate and cost-effective proxy measure for gestational age assessment. Its strong correlation with gestational age, excellent diagnostic accuracy and practical applicability make it an invaluable tool for early identification of preterm newborns, particularly in resource-constrained settings.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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