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Foot Length as a Predictor of Gestational Age in Neonates and its Comparison with the New Ballard Score: A Cross-sectional Study.

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Abstract

Introduction: ccurate assessment of gestational age (GA) is essential for appropriate neonatal management, especially in identifying preterm infants who require timely intervention. Conventional methods such as first-trimester ultrasonography and the New Ballard Score (NBS) may not always be feasible in resource-limited settings. Neonatal foot length has emerged as a simple, inexpensive, and reproducible anthropometric parameter for estimating gestational age. ***Aim:*** To evaluate fetal (neonatal) foot length as a parameter for predicting gestational age and to compare its correlation with the New Ballard Score. ***Materials and Methods:*** This hospital-based cross-sectional study was conducted in the Department of Pediatrics, Government Institute of Medical Sciences , Greater Noida, Uttar Pradesh, India, from July 2025 to July 2026. A total of 204 live singleton neonates with gestational age ranging from 25 to 42 weeks were enrolled. Right foot length was measured within 24 hours of birth using a digital Vernier caliper, and gestational age was assessed using the New Ballard Score. Pearson's correlation coefficient was used to determine the relationship between foot length and gestational age. Statistical significance was considered at $p<0.05$. ***Results:*** The mean gestational age was 36.63±3.62 weeks, while the mean foot length was 74.70±8.14 mm. A strong positive correlation was observed between foot length and gestational age assessed by the New Ballard Score ($r=0.887$, $p<0.001$). Significant positive correlations were also observed among preterm ($r=0.816$, $p<0.001$) and term neonates ($r=0.465$, $p<0.001$). Foot length showed a strong correlation among appropriate-for-gestational-age neonates, whereas correlation was weak among small-for-gestational-age infants. No significant gender-wise differences in foot length or gestational age were observed. ***Conclusion:*** Neonatal foot length demonstrated a strong positive correlation with gestational age and can serve as a simple, rapid, inexpensive, and reliable bedside tool for estimating gestational age. It may be particularly useful in peripheral and resource-limited healthcare settings for early identification and timely referral of high-risk neonates.

Keywords: Foot length; Gestational age; New Ballard Score; Neonate; Prematurity.

INTRODUCTION

Accurate determination of gestational age (GA) is fundamental to neonatal care as it influences immediate clinical management, prognosis, nutritional planning, and long-term neurodevelopmental follow-up. Identification of preterm neonates is particularly important because prematurity remains one of the leading causes of neonatal morbidity and mortality worldwide. Despite substantial reductions in under-five mortality, neonatal deaths continue to account for nearly half of all deaths in children under five years of age, with complications of prematurity contributing significantly to this burden (1,2).

Gestational age is traditionally estimated antenatally using the first day of the last menstrual period (LMP) or first-trimester ultrasonography. Although LMP is simple and inexpensive, its accuracy depends on maternal recall and assumes regular menstrual cycles, making it unreliable in many pregnancies, particularly in low- and middle-income countries where women may have uncertain menstrual histories or limited antenatal care (3,4). First-trimester ultrasonography is considered the gold standard for pregnancy dating; however, its availability remains limited in resource-constrained settings, and its accuracy decreases when performed later in pregnancy (5,6).

In the absence of reliable antenatal dating, postnatal clinical methods such as the New Ballard Score (NBS) are commonly employed to estimate gestational age. The NBS evaluates six physical and six neuromuscular maturity parameters and has been validated for assessment of both term and preterm neonates. However, it requires trained personnel, is relatively time-

consuming, and is subject to inter-observer variability. Furthermore, performing a complete neurological examination may be difficult in critically ill or unstable newborns requiring minimal handling (7,8).

Simple anthropometric measurements have therefore been explored as alternative methods for estimating gestational age. Among these, neonatal foot length has emerged as a practical and reproducible parameter because it can be measured rapidly with minimal equipment and training. Foot length is relatively unaffected by postnatal physiological changes, can be measured even in sick neonates, and has demonstrated a strong correlation with gestational age in several studies conducted across different populations (9–13).

Earlier work by Mercer et al., established fetal foot length as a reliable predictor of gestational age, while subsequent postnatal studies have consistently demonstrated significant correlations between neonatal foot length and gestational maturity assessed using clinical scoring systems or ultrasonography (10–13). Owing to its simplicity, foot length measurement has also been proposed as a useful screening tool for identifying preterm and low-birth-weight infants in peripheral healthcare facilities where sophisticated diagnostic resources and trained personnel may not be available (9,11).

Although several studies have evaluated the relationship between foot length and gestational age, variations in ethnicity, study population, measurement techniques, and reference standards limit the universal applicability of existing data. Furthermore, evidence comparing foot length with the New Ballard Score among different gestational maturity and growth categories in the Indian population remains limited.

Therefore, the present study was undertaken to evaluate neonatal foot length as a predictor of gestational age and to compare its correlation with the New Ballard Score. In addition, the study aimed to assess the usefulness of foot length across gestational maturity and growth subgroups and to determine its potential role as a simple bedside screening tool for early identification and timely referral of high-risk neonates in resource-limited settings.

MATERIALS AND METHODS

Study Design and Participants

This hospital-based cross-sectional study was conducted in the Department of Pediatrics, Government Institute of Medical Sciences , Greater Noida, Uttar Pradesh, India, over a period of one year from July 2025 to July 2026, after obtaining approval from the Institutional Ethics Committee. A total of 204 inborn live singleton neonates with gestational age ranging from 25 to 42 completed weeks were consecutively enrolled in the study.

Neonates born from multiple pregnancies, those with congenital foot deformities (such as congenital talipes equinovarus, rocker-bottom foot and vertical talus), congenital infections and major congenital anomalies were excluded. Sample size was calculated using Buderer's formula for diagnostic studies, yielding a minimum sample size of 204 neonates (14).

Data Collection and Measurements

Demographic details, birth weight and gestational age were recorded for each neonate. Birth weight was measured using a calibrated electronic weighing scale with an accuracy of ±10 g. Based on Fenton growth charts, neonates were classified as Small for Gestational Age (SGA), Appropriate for Gestational Age (AGA) or Large for Gestational Age (LGA). Right foot length was measured within the first 24 hours of life using a digital Vernier caliper with an accuracy of 0.1 mm. Foot length was defined as the distance from the midpoint of the heel to the tip of the longest toe. To minimise the effect of the plantar grasp reflex, the ankle was gently stabilised while keeping the foot in a neutral position. Three consecutive measurements were obtained for each neonate, and the median value was considered for analysis. If two of the three readings were identical, that value was recorded. Gestational age was assessed independently within 24 hours of birth using the New Ballard Score (NBS), which evaluates six physical and six neuromuscular maturity criteria. Neonates were categorised as preterm (<37 completed weeks), term (37–41 weeks and 6 days) and post-term (≥42 completed weeks) according to standard definitions.

Outcome Measures

The primary outcome was to determine the correlation between neonatal foot length and gestational age estimated by the New Ballard Score. Secondary outcomes included evaluation of the correlation between foot length and gestational age within preterm, term and post-term neonates, assessment across growth categories (AGA, SGA and LGA), determination of the utility of foot length in identifying neonates at risk of prematurity, and development of gestational age-specific foot length percentile values for the study population.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) software version 27 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean±standard deviation (SD) or

median with range, while categorical variables were presented as frequencies and percentages. Pearson's correlation coefficient (r) was used to assess the relationship between neonatal foot length and gestational age estimated by the New Ballard Score. Comparisons between groups were performed using appropriate statistical tests. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 204 singleton neonates were enrolled in the study, comprising 107 (52.5%) males and 97 (47.5%) females. Based on gestational maturity, 77 (37.7%) neonates were preterm, 118 (57.8%) were term, and 9 (4.4%) were post-term. According to growth classification, 175 (85.8%) neonates were Appropriate for Gestational Age (AGA), 27 (13.2%) were Small for Gestational Age (SGA), and 2 (1.0%) were Large for Gestational Age (LGA) (table 1).

Table 1: Baseline characteristics of the study population

Characteristic	Value
Gender	
Male, n (%)	107 (52.5)
Female, n (%)	97 (47.5)
Gestational age	
Preterm, n (%)	77 (37.7)
Term, n (%)	118 (57.8)
Post-term, n (%)	9 (4.4)
AGA/SGA/LGA	
AGA, n (%)	175 (85.8)
SGA, n (%)	27 (13.2)
LGA, n (%)	2 (1.0)

The mean gestational age determined by ultrasonography was 36.79±3.64 weeks, while the mean gestational age estimated using the New Ballard Score was 36.63±3.62 weeks. Mean neonatal foot length was 74.70±8.14 mm, and the mean birth weight was 2.64±0.81 kg.

A strong positive correlation was observed between neonatal foot length and gestational age estimated using the New Ballard Score (r=0.887, p<0.001). Subgroup analysis demonstrated a significant positive correlation among preterm (r=0.816, p<0.001) and term neonates (r=0.465, p<0.001), whereas no significant correlation was observed in the post-term group (r=-0.112, p=0.775) (table 2).

Table 2: Correlation between foot length and gestational age assessed by New Ballard Score

Group	Correlation coefficient (r)	p-value
Overall	0.887	<0.001
Preterm	0.816	<0.001
Term	0.465	<0.001
Post-term	-0.112	0.775

Among growth categories, foot length demonstrated a strong positive correlation with gestational age in AGA neonates (r=0.918, p<0.001) and a moderate positive correlation in SGA neonates (r=0.547, p=0.003). Correlation analysis could not be performed in the LGA group because only two neonates were included.

Table 3: Correlation according to growth category

Growth category	Correlation coefficient (r)	p-value
AGA	0.918	<0.001
SGA	0.547	0.003
LGA	Not calculated*	—

*Correlation could not be calculated because of the small sample size (n=2).

Neonates with greater than 37 weeks' gestation had significantly higher foot length compared with those aged ≤37 weeks (p<0.001). Likewise, term neonates had significantly greater foot length than non-term neonates (p<0.001). No statistically significant differences were observed between male and female neonates with respect to gestational age, foot length, birth weight or New Ballard Score (all p>0.05).

Table 5: Comparison of neonatal characteristics by sex

Variable	Male (n=107)	Female (n=97)	p-value
Gestational age by USG (weeks)	36.57±3.85	37.04±3.39	0.351
Gestational age by NBS (weeks)	36.37±3.75	36.91±3.46	0.292
Foot length (mm)	74.47±8.64	74.97±7.58	0.657
Birth weight (kg)	2.64±0.81	2.65±0.81	0.920
New Ballard Score	31.01±9.15	32.07±8.49	0.390

A gestational age-specific percentile chart (5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles) for neonatal foot length was also generated for gestational ages ranging from 25 to 42 weeks to facilitate estimation of gestational age in clinical practice.

DISCUSSION

Accurate estimation of gestational age (GA) is fundamental for appropriate neonatal management, particularly in resource-limited settings where reliable antenatal dating may not always be available. The present study demonstrated a strong positive correlation between neonatal foot length and gestational age assessed using the New Ballard Score (NBS), suggesting that foot length can serve as a simple and reliable anthropometric surrogate for gestational age assessment. In the present study, the overall correlation between foot length and gestational age was strong ($r=0.887$, $p<0.001$). The correlation remained significant among preterm ($r=0.816$) and term neonates ($r=0.465$), while no significant association was observed among post-term infants, probably because only nine neonates belonged to this group. These findings support the concept that neonatal foot length increases proportionately with advancing gestation and can reliably identify preterm infants. Similar observations have been reported by Mercer et al., who first demonstrated a linear relationship between fetal foot length and gestational age throughout pregnancy (10).

Several postnatal studies have also reported findings comparable to the present study. Gavhane et al. observed a strong positive correlation between neonatal foot length and gestational maturity, concluding that foot length is a simple bedside tool for estimating gestational age in newborns (12). Likewise, Pathiyil et al. reported a significant positive correlation between foot length and the New Ballard Score and suggested that foot length measurement could be incorporated into routine neonatal assessment, particularly in peripheral healthcare settings (13). Tergestina et al. further demonstrated that foot length is useful not only for gestational age estimation but also for identifying high-risk neonates requiring early referral (11). The findings of the present study are consistent with these reports and further strengthen the evidence supporting foot length as a practical screening tool.

Subgroup analysis showed that the correlation between foot length and gestational age was strongest among Appropriate for Gestational Age (AGA) neonates ($r=0.918$), whereas only a moderate correlation was observed among Small for Gestational Age (SGA) infants. Correlation analysis could not be performed among Large for Gestational Age (LGA) neonates because only two infants belonged to this category. Similar observations have been reported by Sateesha et al., who demonstrated a stronger correlation in AGA neonates than in SGA or LGA infants, suggesting that fetal growth restriction may influence anthropometric measurements despite similar gestational maturity (15). Saroj et al. also observed that foot length correlated well with gestational age in preterm AGA neonates but showed relatively weaker association among SGA infants (16). These findings indicate that although foot length is a useful predictor of gestational age, growth restriction should be considered while interpreting measurements.

The present study also demonstrated that foot length was significantly greater among neonates with gestational age above 37 weeks compared with those born at or before 37 weeks. This observation highlights the potential utility of foot length measurement as a rapid screening method for identifying prematurity immediately after birth. Since measurement requires only a digital Vernier caliper and minimal training, it can be performed even in sick or unstable neonates requiring minimal handling. Similar conclusions have been drawn by Gidi et al. and Van Wyk and Smith, who recommended foot length as a feasible community-level screening tool in low-resource settings where access to skilled personnel and ultrasonography is limited (9,17). No statistically significant differences were observed between male and female neonates with respect to gestational age, foot length, birth weight or New Ballard Score. This suggests that neonatal foot length is independent of sex and may be applied uniformly in both male and female newborns. Comparable findings have been reported by Srinivasa et al., who also found no significant sex-related differences in neonatal foot length measurements (18).

The major strength of the present study is the inclusion of a relatively adequate sample size with neonates across a wide gestational age spectrum (25–42 weeks). Foot length was measured using a digital Vernier caliper with repeated measurements to minimise observer error, and gestational age assessment was performed using the standard New Ballard Score within 24 hours of birth, thereby improving measurement reliability.

However, certain limitations should be acknowledged. First, gestational age was determined using the New Ballard Score rather than first-trimester ultrasonography, which remains the gold standard for pregnancy dating (5). Second, the number of neonates was not uniformly distributed across all gestational age groups, with very few post-term and LGA infants, limiting subgroup analysis. Third, this was a single-centre study, and therefore the findings may not be directly generalisable to other populations. Larger multicentric studies are warranted to develop population-specific reference charts and validate clinically useful cut-off values for screening preterm neonates. Overall, the findings of the present study support the growing body of evidence that neonatal foot length is a simple, inexpensive and reproducible anthropometric measurement that can reliably estimate gestational age. Incorporating foot length measurement into routine neonatal assessment may facilitate early recognition of preterm infants, particularly in peripheral healthcare facilities where advanced diagnostic resources are unavailable.

CONCLUSION

Neonatal foot length showed a strong positive correlation with gestational age estimated by the New Ballard Score. Being simple, rapid, inexpensive, and non-invasive, foot length measurement can serve as a reliable bedside tool for estimating gestational age, particularly in resource-limited settings where accurate antenatal dating is unavailable. It may facilitate early identification of preterm neonates and timely referral for appropriate neonatal care. Further multicentric studies are recommended to validate these findings and establish population-specific reference standards.

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