ORIGINAL ARTICLE

Role of foot length in predicting the gestational age of a neonate

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ABSTRACT

Introduction: The aim was to study neonatal foot length as a simple method for quick gestational age assessment, which can be done by basic health care personnel, overcoming the technicality required by other assessment methods.

Materials and Methods: A Prospective descriptive study was done. Live-born neonates at Saveetha Medical College and Hospital, Chennai, were enrolled. Gestational age was assessed by New Ballard's Scoring (NBS), and foot length (FL) was measured using the paddle blades of automated digital Vernier callipers within 24 hours, while birth weight was taken within 72 hours of birth. Based on gestational age, babies were grouped into preterm, term and post term and were sub-classified as small for gestational age (SGA), appropriate for gestational age (AGA) and large for gestational age (LGA) based on Lubchenco's intrauterine growth chart. Correlation and regression analysis with a Scatterplot was done.

Results: Out of 150 neonates, term, preterm and post-term were70.3%,28.4%and1.3% while SGA, AGA, and LGA babies were11%, 85% and 4%. respectively. Mean foot length was7.588±0.57. With a range of 5.2-8.4cm. Foot length strongly correlated with gestational age in Preterm AGA, preterm SGA and Term AGA babies (<0.05). The correlation coefficient between foot length and gestational age was higher in preterm babies (R2=0.56) and SGA babies (R2=0.66). Gestational age in 53% of the total study population could be predicted with a regression equation.

Conclusions: Foot length may be useful for quick estimation of gestational age in preterm and term neonates for early referral of newborns requiring special care, and can even be done by basic healthcare personnel.

KEYWORDS:
Foot Length, Gestational Age, Neonate, New Ballard Score, Preterm, Birth Weight

INTRODUCTION

The most vulnerable time for an infant is the first 28 days after birth, which is the neonatal period.[1] It is a known fact that gestational age assessment is challenging and often not available for children born in small towns and rural areas. Few studies have shown that the foot length (FL) of newborns can be used as a simple, feasible technique in detecting high-risk neonates, which makes faster referral to a higher centre for further management. As per the World Health Organization (WHO), nearly 46% of under-five mortality is seen in the neonatal period of life.[2] The majority of neonatal deaths are due to complications secondary to prematurity(43.7%) in our country.[3] Gestational age (GA) is defined as the period from day one of the Last Menstrual Period (LMP) and the day of delivery by the American Academy of Paedaitrics (AAP).[4] GA is described and termed as preterm, term, and post-term. Newborns with GA of <37 completed weeks are Preterm, while Term neonates are born in between 37 weeks to 41 weeks. Babies born after 42 completed weeks of gestation are considered Postterm.[5,6] Furtherly, all neonates can be grouped into Appropriate for Gestational Age (AGA), Small for Gestational Age (SGA) and Large for Gestational Age (LGA) by weight-based classification. Growth charts commonly used for neonates are Lubchenco and Fenton's charts. SGA is <10thcentile and LGA is >90thcentile.[6]

Gestational age plays a crucial role in planning the management and prognosis for neonates. The follow-up schedule of babies also depends on their gestational age at birth. Gestational age is calculated by Naegele's formula, antenatal ultrasound, and by the New Ballard scoring system normally.[7,8] Each method has its own limitations. Naegele's formula was less reliable in places where there is a low literacy rate among pregnant mothers and less awareness of the pattern of ovulation and breastfeeding. Antenatal Ultrasound is the most reliable method for GA calculation, but can be a constraining factor in itself in places where not all pregnant women follow the mandatory antenatal visits and scans in developing countries like India. The New Ballard Score (NBS) assessment is considered one of the definitive methods for assessing gestational age in neonates. The accuracy of NBS is highly subjective and completely relies on the clinical evaluation of the physician and the general status of the newborn, especially in babies with asphyxia.[5] Anthropometric parameters, like birth weight, are generally used to assess intra-uterine growth in newborns, which fairly correlates with gestational age and maturity. A limitation is that birth weight is significantly affected by changes in the neonate's physiological state, including hydration, carbohydrate, fat, protein, and mineral levels.

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Postnatal measurement of foot length is a recently used method to assess gestational maturity in neonates. Studies have shown that newborn foot length shows the least variation among anthropometric parameters in babies with foetal growth restriction.[9]

Pertemps possess a greater risk of morbidity, so they were termed as high-risk babies. Early detection of high-risk neonates in peripheral medical centres and community-level hospitals can reduce neonatal morbidity and mortality to a greater extent. When neonates require intensive care, an exact assessment of gestational maturity may not be possible at all times. Hence, the baby's foot is an easily accessible parameter for GA calculation and does not require specialised training.

Therefore, it is useful to conduct a study to determine whether foot length can be used as a simple, easy, and reliable method for estimating neonatal gestational age and to help in the effective management of babies requiring intensive care.

MATERIALS AND METHODS

This is a prospective observational study conducted at Saveetha Medical College and Hospital from April 2023 to January 2024.

Inclusion criteria were live neonates born in our hospital during the study period.

Exclusion criteria were babies with any physical deformities involving the foot, legs and chromosomal defects.

Newborn babies were enrolled in our study after obtaining parental consent. The neonates were examined strictly with an aseptic protocol, and the foot length of the baby was calculated from the most prominent surface of the baby's left foot to the tip of the great toe with the help of the paddle blades of a Vernier calliper (automated and digital). Those measurements were recorded in centimetres(cm), including decimals. For all babies, foot length was calculated only in the left foot by day one of life. The Birth Weight of the neonates was measured using a digital scale (CIBI) with ±5g accuracy immediately after birth. Along with Weight and foot length, basic details of neonates such as date of birth, APGAR score at one minute and five minutes, gestational age by both Naeglis formula and NBS were documented in a preformed data sheet. According to data entered, newborns were classified into (<37weeks) preterm, (37-42weeks) term and (>42weeks) post-term term which is further sub-classified into LGA/AGA/SGA using the Lubchenco chart.[10]

All data were collected and recorded in an Excel sheet. Correlation and Regression Analysis, along with a Scatter plot, were done using SPSS Software version 17. It was considered statistically significant if $p<0.05$.

RESULTS

The study examined 150 newborns to understand how foot length correlates with gestational age and birth weight. Among the newborns, 54% were male, and 46% were female, with 85% classified as AGA babies, 11% as SGA babies, and 4% as LGA babies. The mean Foot Length in centimetres (cm) in our study was 7.728±0.59, with Term babies showing a mean of 7.94±0.42, preterm 7.53±0.55, and post-term 8.39±0.29.

In preterm newborns, foot length correlated well with birth weight in both SGA ($p=0.030$) and AGA ($p<0.001$) groups, whereas in term neonates, this correlation was observed only in AGA babies ($p<0.001$). In terms of newborns, correlation of foot length to gestational age was present only for AGA ($p<0.001$) babies, while significant correlation of foot length to GA was seen in both preterm SGA ($p=0.005$) and AGA ($p<0.001$) infants. (Table I, Figure 1)

We found that gestational age, as assessed with the Ballard score, correlates well with both birth weight and foot length in preterm AGA and SGA neonates ($p<0.05$). Whereas with term newborns, we find that GA shows significant correlation with both birth weight and foot length only in AGA babies. (Table II)

The linear regression analysis provided an equation for predicting gestational age from foot length, which is Gestational Age=20.79+2.14×(Foot Length). Here, 21.79 is the constant and 2.14 is the slope, indicating that each additional centimetre in foot length corresponds to an increase of about 2.14 weeks in gestational age.

In our study, the regression equation derived prognosticates the gestational age by 53% of the overall study population and strongly predicts gestational age in 56% of preterm and 66% of SGA babies. (Table III)

Table I: Correlation of foot length with birth weight and gestational age

Pair	Preterm		Term		
	SGA (p-value)	AGA (p-value)	SGA (p-value)	AGA (p-value)	LGA (p-value)
Foot length to birth weight	0.679(0.030)	0.478(<0.001)	0.272(0.272)	0.459(<0.001)	0.133(0.789)
Foot length to gestational age	0.789(0.005)	0.626(<0.001)	0.211(0.420)	0.370(<0.001)	0.346(0.459)

p-value less than 0.05 is considered significant; (SGA-Small for gestational age, AGA-Appropriate for gestational age, LGA-Large for gestational age)

Table II: Correlation of gestational age with birth weight and foot length

Pair	Preterm		Term		
	SGA (p-value)	AGA (p-value)	SGA (p-value)	AGA (p-value)	LGA (p-value)
Gestational age to birth weight	0.850(0.003)	0.688(0.000)	0.380(0.117)	0.355(<0.001)	0.662(0.106)
Gestational age to foot length	0.789(0.005)	0.616(<0.001)	0.213(0.430)	0.392(<0.001)	0.346(0.431)

p-value less than 0.05 is considered significant ; (SGA-Small for gestational age, AGA-Appropriate for gestational age, LGA-Large for gestational age)

Table III: Regression analysis of each category among neonates

Variables	Regression equation (y)	R^2 value
Overall	20.79+2.14(FL)	0.535
Preterm	19.596+1.539(FL)	0.56
Term	32.664+0.716(FL)	0.13
Post term	42.153+0.120(FL)	0.446
Weight for gestational age		
SGA	11.340+2.544(FL)	0.662
AGA	22.242+1.897(FL)	0.519
LGA	8.608+2.821(FL)	0.473

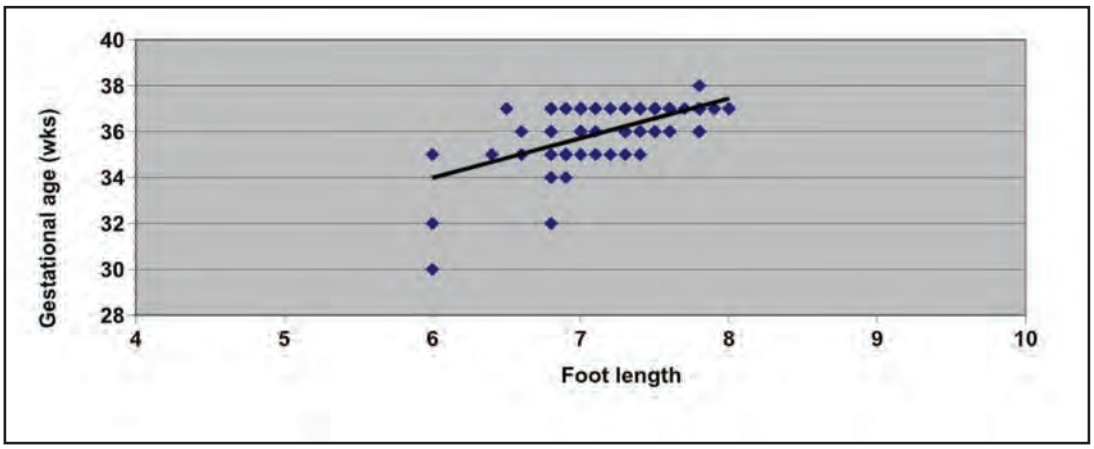

Fig. 1: Scatter plot of the Correlation between Foot length and Gestational age in Preterm

DISCUSSION

In the current study, the distribution of term newborns was 11% SGA, 85% AGA, and 4% LGA, while for preterm newborns, the distribution was 11% SGA, 88% AGA, and 1% LGA. Comparatively, Srivastava et al. reported that term newborns were 75% AGA and 24.7% SGA, whereas preterm newborns were 74% AGA and 24% SGA.[11] Shah et al. found newborns (term) to be 78.4% AGA, 12.5% SGA, and 2% LGA.[12] Due to the small size of the post-term group, it was not included in the correlation analysis.

Although all studies indicate a linear relationship between foot length and gestational age, the correlation coefficients vary across studies. The strength of this correlation varies across gestational age groups. James et al., reported an upward linear connection between foot length and for both AGA and SGA babies across all gestational ages, with particularly strong correlations observed in preterm, similar to the findings in the current study, with significant correlation of foot length with gestational age in Preterm AGA, preterm SGA and Term AGA babies (<0.05).[13]

Gohil et al., also found notable relationships between foot length and birth weight in both term and preterm neonates.[14] However, while Nabiwemba et al., study demonstrated a notable connection between foot length and birth weight in term SGA and AGA babies, the present study found a strong interrelation between foot length and birth weight only in term AGA babies.

While a positive interrelation between foot length and measures such as GA and birth weight was observed across all domains, both James et al. and Nabiwemba et al., studies, as well as the present study, noted a stronger correlation in preterm babies.[13,15]

In this study, the ability to prognosticate GA using foot length via the regression equation was 53% (R^2=0.535) for the overall population, with 56% accuracy in preterm infants and 66% in SGA babies. In contrast, Nimii et al., reported a prediction accuracy of 65% (R^2=0.65), and Wyk et al. reported 76% (R^2=0.765).[16-18]

This study has its own limitations, as it was conducted in a single hospital centre, and the number of neonates varied across gestational age categories. Although obstetric dating was performed using Naegele's formula, there remains a possibility of inaccuracies in estimating gestational age, leading to either overestimation or underestimation. Thus, the results may affect the applicability of the study findings to the general population. Hence, multi-centric, community-based studies may be necessary for further validation.

CONCLUSION

In conclusion, foot length is a practical alternative for assessing gestational age, particularly in preterm neonates and term AGA babies. It is a straightforward measurement that does not require specialised training, making it a valuable tool for early identification and timely referral of

newborns who may need specialised newborn care. Further study in large populations and various medical centres is the scope for future research.

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REFERENCES

1. Ananth CV. Menstrual versus clinical estimate of gestational age dating in the United States: temporal trends and variability in indices of perinatal outcomes. Paediatr Perinat Epidemiol 2007; 21 Suppl 2(s2): 22-30.
2. Newborn mortality [Internet]. World Health Organization; [cited 2025 Nov 4]. Available from: https://www.who.int/news-room/fact-sheets/detail/newborn-mortality
3. Sankar MJ, Neogi SB, Sharma J, Chauhan M, Srivastava R, Prabhakar PK, et al. State of newborn health in India. J Perinatol 2016; 36(s3): S3-8.
4. Engle WA, American Academy of Pediatrics Committee on Fetus and Newborn. Age terminology during the perinatal period. Pediatrics 2004; 114(5): 1362-4.
5. Gabriel M, Moreiras M, Fleixas L, Gallego D, Alonso P, Bértolo C, et al. Valoración del test de Ballard en la determinación de la edad gestacional. An Pediatr (Barc) 2006; 64(2): 140-5.
6. Lee AC, Panchal P, Folger L, Whelan H, Whelan R, Rosner B, et al. Diagnostic accuracy of neonatal assessment for gestational age determination: A systematic review. Pediatrics 2017;140(6): e20171423.
7. Stevenson A, Joolay Y, Levetan C, Price C, Tooke L. A comparison of the accuracy of various methods of postnatal Gestational Age estimation; Including Ballard score, foot length, vascularity of the anterior lens, last menstrual period and also a clinician's non-structured assessment. J Trop Pediatr 2021; 67(1): fmaa113.
8. Tikmani SS, Brown N, Inayat A, Mårtensson A, Saleem S, Mårtensson T. Diagnostic accuracy of footlength measurement for identification of preterm newborn in rural Sindh, Pakistan. BMJ Paediatric Open 2024; 8(1): e002316.
9. Folger LV, Panchal P, Eglo vitch M, Whelan R, Lee AC. Diagnostic accuracy of neonatal foot length to identify preterm and low birthweight infants: a systematic review and meta-analysis. BMJ Glob Health 2020; 5(11): e002976.
10. Lubchenco Lo, Hansman C, Dressler M, Boyd E. Intrauterine Growth As Estimated From Liveborn Birth-Weight Data At 24 To 42 Weeks Of Gestation. Pediatrics 1963 Nov; 32: 793-800.
11. Cutland CL, Lackritz EM, Mallett-Moore T, Bardají A, Chandrasekaran R, Lahariya C, et al. Brighton Collaboration Low Birth Weight Working Group. Low birth weight: Case definition & guidelines for data collection, analysis, and presentation of maternal immunization safety data. Vaccine 2017; 35: 6492-500.
12. Tergestina M, Chandran S, Kumar M, Rebekah G, Ross BJ. Foot length for gestational age assessment and identification of high-risk infants: A hospital-based cross-sectional study. J Trop Pediatr 2021; 67(4): fmab010.
13. James DK, Dryburgh EH, Chiswick ML. Foot length--a new and potentially useful measurement in the neonate. Arch Dis Child 1979; 54(3): 226-30.
14. Gohil JR, Sosi M, Vani SN, Desai AB. Footlength measurement in the neonate. Indian J Pediatr 1991; 58(5): 675-7.
15. Nabiwemba E, Marchant T, Namazzi G, Kadobera D, Waiswa P. Identifying high-risk babies born in the community using foot length measurement at birth in Uganda: Predicting at-risk newborns using foot length. Child Care Health Dev 2013; 39(1): 20-6.
16. Niimi S, Kimura T, Saiki R, Kanda H, Okamatsu Y, Goto M, et al. Estimated gestational age from infant's foot length in Japanese. Cureus 2022; 14(12): e32991.
17. Wyk LV, Smith J. Postnatal Foot Length to Determine Gestational Age: A Pilot Study. J Trop Pediatr 2016; 62(2): 144-51.
18. Dagnew N, Tazebew A, Ayinalem A, Muche A. Measuring newborn foot length to estimate gestational age in a high risk Northwest Ethiopian population. PLoS One 2020; 15(8): e0238169.