MAK HILL Publications International Journal of Tropical Medicine

Research Article
doi: 10.36478/makijtm.2024.4.55.59

OPEN ACCESS

Key Words
Foot length, neonates, gestational age, birth weight, anthropometry, low birth weight

Corresponding Author
Sanjivani Deepak Maslekar, Department of Paediatrics, Mamata Medical College, Khammam, India
sanjivanimaslekar@gmail.com

Author Designation
[1]Associate Professor
[2]Post Graduate
[3]Professor

Received: 20 August 2024
Accepted: 29 September 2024
Published: 4 October 2024

Citation: Sanjivani Deepak Maslekar, Maddiboina Hemanth Kumar and G. Somaiah, 2024. Validation of Foot Length in Prediction of Gestational Maturity and Birth Weight in Neonates. Int. J. Trop. Med., 19: 55-59, doi: 10.36478/makijtm. 2024.4.55.59

Validation of Foot Length in Prediction of Gestational Maturity and Birth Weight in Neonates

[1]Sanjivani Deepak Maslekar, [2]Maddiboina Hemanth Kumar and [3]G. Somaiah
[1-3]Department of Paediatrics, Mamata Medical College, Khammam, India

ABSTRACT
Early identification of low birth weight (LBW) is critical for reducing neonatal mortality, particularly in resource-limited settings. This study aimed to explore the correlation between foot length and other anthropometric measurements, including gestational age, birth weight, head circumference and crown heel length, in 200 neonates. Conducted at Mamata Medical College and General Hospital from August 2022-May 2024, measurements were taken within 72 hours of birth. The majority of neonates were term (60%) and appropriate for gestational age (AGA) (85%). Foot length showed a significant positive correlation with gestational age and birth weight, especially in preterm neonates (r=0.688 for preterm AGA, r=0.542 for term AGA). The highest correlation was observed between foot length and crown heel length in preterm SGA neonates (r=0.925). These findings suggest that foot length is a simple, reliable tool for estimating gestational age and birth weight in neonates, particularly useful in resource-limited settings and for sick, preterm infants requiring minimal handling.

INTRODUCTION

India experiences one of the highest rates of neonatal mortality, with approximately one million newborn deaths each year, contributing to a quarter of global neonatal mortality[1,2]. The country has seen a significant reduction in neonatal mortality over the years. Between 1980 and 1990, India's neonatal mortality rate (NMR) decreased by 25%, from 69-53 per 1,000 live births. From 1991-2000, the NMR further declined by 15%, from 51-44 per 1,000 live births and between 2001 and 2009, it dropped by another 15%, from 40-34 per 1,000 live births[3].

In recent years, India has continued to make progress. From 2010-2020, the NMR decreased by 25%, from 34-26 per 1,000 live births. However, there remains a significant disparity between urban and rural areas, with rural neonatal mortality rates 50% higher than in urban areas (42.5 per 1,000 live births in rural areas compared to 28.5 per 1,000 live births in urban areas), according to the National Family Health Survey (NFHS-3)[4].

The leading causes of neonatal deaths in India include prematurity, infections, birth asphyxia and low birth weight, which account for 35%, 33%, 20% and 12% of neonatal deaths, respectively[5].

Despite the high neonatal mortality rate, rural India struggles with inadequately equipped public health facilities, a shortage of pediatricians and a lack of essential medical equipment. Birth weight and gestational age are critical indicators of neonatal mortality risk. Generally, shorter gestational duration correlates with higher neonatal mortality and similarly, lower birth weight is associated with increased mortality[6].

These challenges highlight the importance of early identification of low birth weight and preterm infants in rural settings, where access to medical care is limited. Timely referral to higher centers for high-risk neonates is crucial. However, rural areas often lack essential resources such as trained healthcare staff and basic equipment like electronic weighing machines[6].

This underlines the need for an alternative, cost-effective method for estimating birth weight and gestational age that can be easily implemented in resource-limited settings. The Ballard score is commonly used to assess gestational age, but it requires skilled personnel. Numerous studies have explored substitute measurements for estimating gestational age and birth weight.

An ideal alternative method should be reliable, affordable and show a strong correlation with birth weight and gestational age across various newborn groups, including preterm, term, post-term, small-for-gestational-age (SGA), appropriate-for-gestational-age (AGA) and large-for-gestational-age (LGA) infants[6]. Moreover, this method should be easy to use, even by less experienced healthcare workers, with minimal intra-and inter-observer variability. Research conducted by Resu H *et al.* found that foot length in most newborns had a strong correlation with gestational maturity and birth weight[7]. The study concluded that foot length measurement could be an effective and practical tool for assessing gestational age and birth weight, particularly in rural areas, where it can be performed by ASHA and Anganwadi workers without disturbing the newborn[7]. The aim was to study the correlation between foot length and gestational age in preterm, term and post-term neonates and to evaluate whether foot length can serve as a proxy measurement for assessing birth weight and gestational age.

MATERIALS AND METHODS

The study involved a sample of 200 newborns, selected through simple random sampling, born at Mamata Medical College and General Hospital, Khammam, between August 2022 and May 2024 (a total of 22 months).

Inclusion Criteria:

- All newborns admitted to the postnatal ward and NICU at Mamata General Hospital, Khammam, during the study period.

Exclusion Criteria:

- Newborns with skeletal deformities of the foot.
- Newborns whose parents declined to provide consent.

Method of Data Collection: Data was collected using a standard proforma designed to meet the objectives of the study.

- **Head Circumference:** Measured using a flexible, non-stretchable fiber measuring tape. The tape was positioned around the occipital prominence at the back, just above the ear lobes on the sides and just above the supraorbital ridge at the front. Measurements were recorded with an accuracy of one millimeter and documented in centimeters.
- **Crown-Heel Length:** Measured using an infantometer, with the assistance of another person to straighten the baby's lower limbs. The measurement was recorded in centimeters.
- **Gestational Age:** Assessed using the modified Ballard score.
- **Foot Length:** Measured using sliding calipers with millimeter precision. Foot length was measured from the posterior-most prominence of the heel to the tip of the longest toe on the right foot. Gentle pressure was applied to flatten the ventral surface of the foot during measurement. The length was documented in centimeters.
- **Birth Weight:** Measured using an electronic weighing scale with an accuracy of±5 grams. All

clothing was removed from the newborn before weighing. Newborns were classified into preterm, term and post-term groups based on gestational age. Newborns with <37 weeks of gestation were classified as preterm, while those with 42 or more weeks of gestation were classified as post-term.

Statistical Analysis: The correlation between foot length and other parameters such as gestational age and birth weight was analyzed using correlation and regression analysis. Correlation coefficient (r) and R-squared (R^2) values were derived for the newborns who were part of the analysis. A $p<0.05$ was considered statistically significant. A regression equation was formulated to predict gestational age based on foot length in different groups of newborns. Appropriate statistical tests were applied and the results were drawn accordingly.

RESULTS AND DISCUSSIONS

Table 1: Distribution of Newborns by Birth Weight and Gender

Birth Weight (kg)	Male Number	Female %	Total Number
<2.5	34	34%	30
2.5-3.5	64	64%	68
>3.5	2	2%	2
Total	100	100%	100

The table 1 presents the distribution of 200 newborns by birth weight and gender. The majority of newborns (66%) had a birth weight between 2.5-3.5 kg, indicating a normal birth weight range, with a slightly higher percentage among females (68%) compared to males (64%). About 32% of the newborns weighed<2.5 kg, classified as low birth weight, with a slightly higher percentage in males (34%) compared to females (30%). Only a small proportion (2%) had a birth weight exceeding 3.5 kg, with an equal distribution between males and females.

Table 2: Classification of Newborns by Maturity

Maturity Status	Number	Percentage
Term	120	60%
Preterm	60	30%
Post-term	20	10%
Total	200	100%

The above table 2 shows the distribution of newborns based on their maturity status term, preterm and post-term. The majority (60%) of the newborns is term, 30% are preterm and 10% are post-term. This indicates that most newborns were born at full term, while smaller percentages were either born prematurely or after the expected delivery date.

Table 3: Classification of Newborns by Weight-for-Gestational Age

Classification	Number	Percentage
AGA	170	85%
SGA	26	13%
LGA	4	2%
Total	200	100%

This table 3 summarizes the classification of newborns based on their weight relative to their gestational age, the distribution of newborns classified as Appropriate-for-Gestational Age (AGA), Small-for-Gestational Age (SGA) and Large-for-Gestational Age (LGA). The majority of newborns (85%) fall under the AGA category, indicating that their weight is appropriate for their gestational age. A smaller proportion of newborns (13%) are classified as SGA, meaning they have a lower weight than expected for their gestational age and 2% are classified as LGA, meaning they have a higher weight than expected.

Table 4: Descriptive Statistics of Gestational Age for Different Groups of Babies

Maturity	Number of Subjects	Range (kg)	Mean (kg)	Standard Deviation (kg)	95% CI Lower Bound	95% CI Upper Bound
Preterm SGA	8	0.7-1.8	1.4063	0.38026	1.0883	1.7242
Preterm AGA	51	1.25-2.8	2.1088	0.43666	1.986	2.2316
Preterm LGA	1	3.3	3.3	0	0	0
Term SGA	15	2-2.2	2.14	0.09103	2.0896	2.1904
Term AGA	103	2.4-3.6	2.817	0.28949	2.7604	2.8736
Term LGA	2	3.8-3.85	3.825	0.03536	3.5073	4.1427
Post-term SGA	3	2.4-2.7	2.5333	0.11547	2.2465	2.8202
Post-term AGA	16	2.1-3.5	3.0563	0.23656	2.9302	3.1823
Post-term LGA	1	4.25	4.25	0	0	0
Total	200	0.7-4.25	2.8263	0.176092	1.8454	2.1294

The table 4 presents the descriptive statistics of birth weight across different maturity groups of newborns, categorized as preterm, term and post-term and further divided into small-for-gestational-age (SGA), appropriate-for-gestational-age (AGA) and large-for-gestational-age (LGA) categories. It shows the number of subjects in each group, the birth weight range, mean birth weight, standard deviation and 95% confidence intervals. The mean birth weight ranges from 1.4 kg in the preterm SGA group to 4.25 kg in the post-term LGA group. The table highlights that term AGA babies had an average birth weight of 2.82 kg, with preterm and post-term groups having lower and higher averages, respectively. Standard deviations indicate variability within groups and confidence intervals provide the range where the true mean is likely to fall.

Table 5: Correlation Between Foot Length and Other Variables for Preterm AGA

Anthropometric Variables	Number of Subjects	Correlation (r)	R-square (r2)
Gestational age (weeks)	51	0.688	0.473
Birth weight (kg)	51	0.708	0.501
Head circumference (CMS)	51	0.701	0.491
Crown heel length (CMS)	51	0.724	0.524

From this table 5, it could be observed that the foot length correlated significantly ($p<0.05$) with gestational age, birth weight and head circumference and crown heel length. Correlation coefficient (r-value) of all the parameters was highly positive. Maximum correlation was observed with Crown heel length (r=0.724) which indicates strong positive association between them.
This scatter diagram figure 1 of the preterm AGA group shows correlation of foot length and other parameters like gestational age, birth weight, head circumference

and crown heel length. It is evident from the figure that the foot length correlated significantly with all the variables. Maximum correlation was with crown heel length (r=0.724).

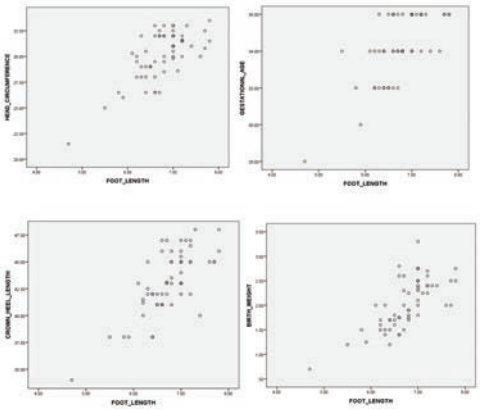

Fig. 1: Scatter Diagram of the Preterm AGA Group

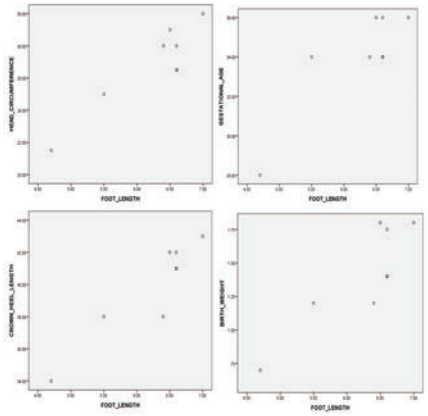

Fig. 2: Scatter Diagram of the Preterm SGA Group

This scatter diagram fig 2 of the preterm SGA group shows correlation of foot length and other parameters. This figure shows significant correlation of foot length with all the four parameters, maximum being with Crown heel length (r = 0.925).

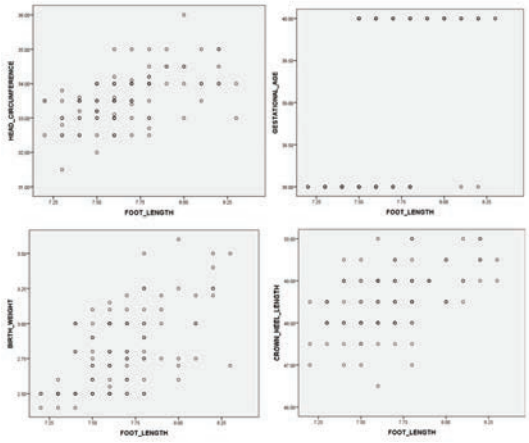

Fig. 3: Scatter Diagram of the Term AGA Group

This scatter diagram (Figure 3) shows correlation of foot length and other variables interm AGA group. Foot length correlated significantly with all the variables, maximum being with birth weight (r-0.597).

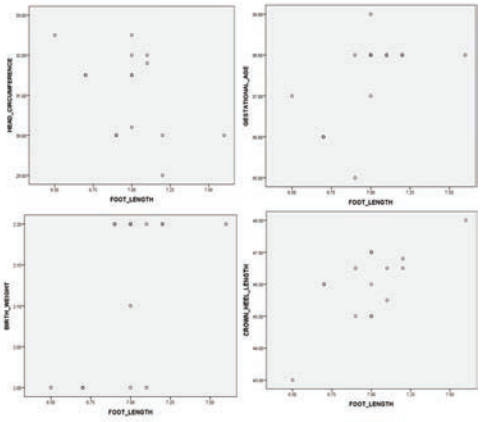

Fig. 4: Scatter Diagram of the Term SGA Group

This scatter diagram (Figure 4) shows correlation of foot length and other parameters like gestational age, birth weight, head circumference and crown heel length interm SGA group of babies. It can be observed that foot length correlated significantly with all the parameters. Maximum correlation was with Crown heel length (r=0.765).

Table 6: Correlation Between Foot Length and Other Variables for Post-Term SGA

Anthropometric Variables	Number of Subjects	Correlation ®	R-square (r2)	P-value
Gestational age (weeks)	3	0.189	0.035	0.439
Birth weight (kg)	3	1	1	0.00
Head circumference (CMS)	3	0.419	0.175	0.362
Crown heel length (CMS)	3	0.189	0.032	0.439

From this table 6, it could be observed that foot length correlated ($p<0.05$) only with birth weight (r=0.434). There was no correlation between foot length and other variables.

Table 7: Regression Equation of Gestational Age on Foot Length

Maturity	Dependent variable	Regression equation
Preterm AGA	Foot length	GA=10.6+3.5FL
Preterm SGA	Foot length	GA=18.6+3.5FL
Term AGA	Foot length	GA=29.29+1.13FL
Term SGA	Foot length	GA=30.51+0.81FL
Term LGA	Foot length	GA=34.98+0.39FL
Post-term AGA	Foot length	GA=39.65+0.63FL
Post-term SGA	Foot length	GA=37.56+0.28FL

The regression equation for gestational age was derived with foot length as the dependent variable and gestational age as the independent variable.

The early identification of low birth weight (LBW) babies is crucial to reduce neonatal mortality, especially in developing countries like India. Due to the limited availability of sophisticated equipment and the need for minimal handling of sick neonates, foot length has emerged as a simple, non-invasive anthropometric measurement that can be used as a proxy for birth weight and gestational age. The present study explored

the correlation of foot length with gestational age, birth weight, head circumference and crown heel length in 200 neonates.

In the study, 60% of the neonates were term, 30% preterm and 10% post-term. The majority (85%) were classified as appropriate for gestational age (AGA), with 13% being small for gestational age (SGA) and 2% large for gestational age (LGA). These findings are consistent with previous studies such as those by Saroj[8], who reported similar distributions among term and preterm neonates. Additionally, the birth weight range in the current study (0.7-4.25 kg) and the mean birth weight of 2.82 kg were comparable to other studies, such as those by Huque[9] and Hossain[10], who found mean birth weights of 2.679 kg and 3.5 kg, respectively.

The study showed that foot length correlated significantly with gestational age and birth weight, with preterm neonates displaying a stronger correlation (r=0.688 in preterm AGA and r=0.868 in preterm SGA) than term neonates (r=0.542 in term AGA and r=0.459 in term SGA). This finding aligns with research by Gohil[11], who also reported significant correlations between foot length and other body measurements in preterm and term neonates.

In particular, foot length had the highest correlation with birth weight in preterm SGA neonates (r=0.861), which is consistent with findings from James[12] and Kulkarni[13], who demonstrated strong correlations between foot length and birth weight in preterm neonates. The present study also found significant correlations with crown heel length and head circumference, especially in preterm and term neonates, with the highest correlation in preterm SGA neonates for crown heel length (r=0.925).

The study's results support the use of foot length as a reliable proxy for assessing gestational age and birth weight in neonates, especially in resource-limited settings. Foot length can be quickly measured, even in sick neonates, making it a valuable tool in both clinical and community settings. However, the study acknowledges limitations, including its relatively small sample size and hospital-based design, which may not fully represent the broader population. Larger studies in community settings would help validate these findings.

CONCLUSION

In conclusion, the findings of this study align with previous research, demonstrating that foot length is a reliable and easy-to-use measurement that correlates well with gestational age and birth weight, particularly in preterm neonates. This can be especially useful in settings where more sophisticated tools are unavailable, aiding in the early identification of LBW babies and potentially improving neonatal outcomes.

REFERENCES

1. Lawn, J.E., S. Cousens and J. Zupan, 2005. 4 million neonatal deaths: When? Where? Why? Lancet, 365: 891-900.
2. Upadhyay, R.P., P. Chinnakali, O. Odukoya, K. Yadav and S. Sinha et al., 2012. High Neonatal Mortality Rates in Rural India: What Options to Explore? Pediatr.s, 2012:
3. Das, U., B. Chaplot and H.M. Azamathulla, 2021. The role of place of delivery in preventing neonatal and infant mortality rate in India. Geographies, 1: 47-62.
4. Raman, T.R., A. Devgan, S.L. Sood, A. Gupta and B. Ravichander, 1998. Low birth weight babies: incidence and risk factors. Med. J. Armed Forces India, 54: 191-195.
5. Pratinidhi, A.K., A.N. Shrotri, U. Shah and N.D. Bodhani, 1986. Domiciliary care of low birth weight neonatesIndian J. Pediatr.s, 53: 87-92.
6. Srivastava, A., U. Sharma and S. Kumar, 2015. To study correlation of foot length and gestational age of new born by new Ballard score. Int J Res Med Sci., 3: 3119-3122.
7. Saroj, A.K., J.N. Sharma and M. Singh, 2016. Measurement of Neonatal Foot Length to Identify Low Birth Weight Babies: a cross-sectional hospital based study. J Dental Med Sci., 15: 49-55.
8. Huque, F. and Z. Hussain, 1991. Detection of low birth-weight new born babies by anthropometric measurements in Bangladesh. Indian J. Pediatr.s, 58: 223-231.
9. Hossain, M.M., M. Habib and H.L. DuPont, 1994. Association between birth weight and birth arm circumference of neonates in rural Egypt. Indian J. Pediatr.s, 61: 81-87.
10. Gohil, J.R., M. Sosi, S.N. Vani and A.B. Desai, 1991. Footlength measurement in the neonate. Indian J. Pediatr.s, 58: 675-677.
11. James, D.K., E.H. Dryburgh and M.L. Chiswick, 1979. Foot length--a new and potentially useful measurement in the neonate.. Arch. Dis. Childhood, 54: 226-230.
12. Kulkarni, M.L. and N.K. Rajendran, 1992. Values for foot length in newborns. Indian pedi., 29: 507-509.