ORIGINAL ARTICLE

Assessment of gestational age using newborn foot length: A prospective cross-sectional study

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Received: 12-09-2023
Accepted: 15-10-2023

How to cite this article:
Kashyap R, Rai PL, Sharma SK. Assessment of Gestational Age using Newborn Foot Length: A Prospective Cross-Sectional Study. Int J Adv Integ Med Sci 2023;8(3):6-10.

Source of Support: Nil,
Conflicts of Interest: None declared.

Background: Accurate assessment of gestational age and birth weight is crucial for neonatal care. Foot length has been proposed as a simple and reliable method for estimating gestational age. **Objectives:** The study aimed to investigate the correlation between foot length, gestational age, and anthropometric measurements in newborns. **Materials and Methods:** Prospective cross-sectional study of 230 newborns, measuring foot length, gestational age, birth weight, head circumference, and crown-heel length. **Results:** Significant positive correlations were found between foot length and gestational age ($r = 0.73$, $P < 0.001$), birth weight ($r = 0.73$, $P < 0.001$), and head circumference ($r = 0.54$, $P < 0.001$). Strong correlations were also observed between foot length and gestational age across different term pregnancy and birth size classifications. **Conclusion:** Foot length is a reliable proxy measurement for gestational age and birth weight assessment, particularly in resource-limited settings.

KEY WORDS: Anthropometric measurements, birth weight, foot length, Gestational age, neonatal care, resource-limited settings

INTRODUCTION

The baby's survival is directly correlated with birth weight and gestational age. Their survival rate will increase with higher birth weight and gestational age, and vice versa. Prenatal ultrasound scan results and the last menstrual period (LMP) can be taken into consideration to evaluate the age of gestation. Using the New Ballard and Dubowitz scoring system, postnatal it can be evaluated postnatally. Because LMP dating assumes a 28-day menstrual cycle, ignores ovulation delays, and can result in errors of 1–4 weeks for women with irregular cycles, it cannot be used alone for gestational assessment. When performed earlier than 20 weeks, antenatal ultrasound scanning is regarded as the gold standard for evaluating the age of GA.[1] Over the past 30 years, numerous equations have been published that describe the relationship between gestational age and the fetal biometric parameters: gestational sac mean diameter, crown rump length, foot length (FL), biparietal diameter, and abdominal circumference. Early antenatal ultrasound is proven to be an objective and reliable method of determining gestational age.[2]

In India, prematurity and its complications are responsible for approximately 35% of neonatal deaths, while globally the figure is 28%. Birth weight is the most significant predictor of survival, growth, and overall development. India has a higher percentage of low birth weight (LBW) babies than the rest of the world.[3] Due to their susceptibility to infections and inability to maintain the necessary nutrition, LBW is linked to a high death rate.

In developing nations such as India, access to medical professionals and technologies is restricted, particularly in rural areas. During their pregnancy, <2 thirds of rural females get their first trimester scanned. Dubowitz and New Ballard's scores are determined by factors related to neurological and physical development. It takes trained specialists to use these scoring systems to evaluate the age of gestation.[4-6]

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Preterm babies have a higher survival rate when they are identified early and referred to higher centers. To detect prematurity as soon as possible in a rural setting, a straightforward alternative that does not require advanced technology or the expertise of a trained professional is needed. Historically, a range of anthropometric measurements, that includes the circumference of the head as well as the circumference of chest, and heel crown length, were attempted to determine gestational age.[7-10] Because foot length has very little inter and intraobserver variability and is therefore easy to measure, even by a non-health worker, it is used in this study as a preliminary tool to determine the age of gestation of the newborn.

Hence, foot length is one such parameter which is simple inexpensive and practical method to identify highly vulnerable preterm newborn immediately after birth. It can be easily measured in extremely preterm and sick neonates without disturbing the baby. Foot length can be used as a proxy measurement for gestational age and birth weight assessment. Not many studies have been reported to be done on correlation of foot length with gestational age and more studies are required to validate this correlation.

The present study is conducted to find a correlation between foot length, gestational age, and other anthropometric and clinical variation.

MATERIALS AND METHODS

The present study was conducted among 230 newborns in the Department of Paediatrics at Rohilkhand Medical College and Hospital in Bareilly, Uttar Pradesh. The research was designed as a prospective cross-sectional study, which took place over a 1-year period. The study included all live neonates born in the hospital during the study period, provided they met certain criteria. However, neonates with specific conditions were excluded from the study. These exclusions included neonates with congenital skeletal deformities of the foot, lower limb edema, foot asymmetries, or those whose parents refused to give consent for their participation. By establishing these inclusion and exclusion criteria, the study aimed to ensure a homogeneous population and minimize potential biases that could impact the accuracy of the results.

The study utilized various tools to collect data on the newborns. These included a transparent stiff ruler for measuring foot length, a flexible and non-stretchable measuring tape for measuring head circumference, an infant meter for measuring crown-heel length, and an electric weighing scale for measuring weight. These tools were carefully selected to ensure accurate and reliable measurements, which were essential for the study's objectives. By using these standardized tools, the researchers aimed to minimize errors and ensure consistency in data collection.

The estimation of foot length was conducted using a transparent plastic rigid ruler. Foot length was determined by measuring the distance from the back of the heels to the point of the big toe on the right foot. The feet length was documented in centimetre up to error of 0.01.

Head circumference was measured using flexible, non-stretchable measuring tape. This tape will be encircling the occipital prominence posteriorly, just above the ear lobe laterally and just above the supra orbital ridge anteriorly by cross tape method. Measurement was done to the accuracy of a millimeter. Head circumference was documented in centimeter. Length from crown to heel was evaluated using infantometer. An assistant's help was sought to do the length measurement. The child should be placed in supine position on the infantometer with his/her knees extended completely and feet at right angles to the lower legs. Baby's head was held against the fixed board, while the sliding board is moved closely to touch the heals. Measurement will be documented in centimeter upto an error of 0.01. Weight was measured using electronic weighing scale. The scale accuracy of ± 0.001 g. The baby was weighed without clothes. Babies were grouped into preterm, term and post term categories. Babies <37th week of gestation was counted in preterm group. Baby's more than 42 weeks of gestation was counted in the post-term age group. All the three groups of babies were categorized into these: small for gestational age (SGA), and also appropriate for gestational age (AGA), and large for gestational age (LGA) groups. This classification was done using Lubchenco Intrauterine growth curves.

The data were entered in Statistical Package for the Social Science; licensed version) 23.0. Descriptive analysis was done by calculating proportions, means and standard deviation. The Chi-square test was utilized to analyze the frequency differences between the two groups: Correlation and regression analysis of data using Pearson's correlation coefficient. ($P < 0.05$ level of significance).

RESULTS

The study of 230 newborns found that 19.56% were mall for gestational age (SGA), 70.86% were AGA, and 9.56% were LGA (Table 1). Males accounted for 52.17% of the sample. The socio-economic status of the participants varied, with 6.52% from the upper class, 13.04% from the upper middle class, 26.08% from the middle class, 29.56% from the lower middle class, and 24.78% from the lower class. This distribution highlights a significant proportion of participants from less affluent backgrounds (Table 1).

The study's analysis of newborns based on term pregnancy revealed a detailed distribution among pre-term, term, and post-term babies, reflecting a diverse neonatal demographic (Table 2). Specifically, 57 newborns were categorized as pre-term, constituting 24.78% of the study populace, which highlights a significant segment of the cohort born before reaching 37 weeks of gestation. The highest number of the participants, numbering 145 or 63.04%, fell into the term category, being born between 37 and 42 weeks of gestation. This suggests that a substantial portion of the newly born children were delivered within the

Table 1: Describing the study participants as per gestational age, gender and socioeconomic status

Parameters	No of babies	Percentage
Gestational age		
SGA	45	19.56
AGA	163	70.86
LGA	22	9.56
Gender		
Male	120	52.17
Female	110	47.82
Socioeconomic status		
Upper class	15	6.52
Upper middle class	30	13.04
Middle class	60	26.08
Lower middle class	68	29.56
Lower class	57	24.78

SGA: Small for gestational age, AGA: Appropriate for gestational age, LGA: Large for gestational age

Table 2: Describing the study participants as per term pregnancy

Term pregnancy	No of babies	Percentage
Pre-term (<37 week)	57	24.78
Term (37–42 weeks)	145	63.04
Post-term (>42 weeks)	28	12.17
Total	230	100

standard gestational period, indicative of normal pregnancy durations. Meanwhile, 28 babies, accounting for 12.17% of the sample, were classified as post-term, having been born after 42 weeks of gestation.

The detailed examination of the relationship between birth weight and foot length in newborns taken into consideration in the study underscores a significant correlation between these two pivotal measures of neonatal development. The average birth weight was found to be 2.6154 kg, with a standard deviation of 0.642, indicating variability in the weights of the newborns within the cohort. The average length of foot was recorded at 75.54 mm, with a standard deviation of 6.495, showing a similar range of variation in foot sizes among the participants. A notable correlation coefficient (r value) of 0.73 between birth weight and foot length signifies highly positive association, suggesting that increases in birth weight are associated with increases in foot length. The statistical significance of this correlation is further emphasized by a $P = 0.001$, firmly establishing the relationship of weight at birth and foot length as not only statistically significant but also potentially indicative of underlying biological and developmental patterns (Table 3).

The study's analysis of the association in the foot length and age of gestation across different categories of term pregnancy and birth size classifications revealed significant findings. For preterm babies, with a mean GA of 34.641 weeks and a feet length of 69.485 mm, a strong correlation coefficient (r value) of 0.76 and a $P = 0.001$ indicated a significant positive association between foot length and GA. Similarly, term babies, with a mean GA of 38.214 weeks and a foot length of 77.754 mm, demonstrated a moderate correlation (r = 0.54) with the same level of statistical significance. Post-term babies showed an even stronger correlation (r = 0.77) between GA and foot length, with means of 42.317 weeks and 73.147 mm, respectively. Furthermore, when analyzing by birth size classification, SGA babies had a mean GA of 37.221 weeks and a foot length of 74.579 mm, showing the highest correlation (r = 0.81). AGA babies and LGA babies also showed strong correlations of 0.76 and 0.75, respectively, with all groups exhibiting a $P = 0.001$, signifying the statistical significance of these correlations (Table 4).

Table 3: The relationship between newborn weight and length of foot

Variables	Mean	SD	Correlation coefficient (r value)	*P*-value
Birth weight (kg)	2.6154	0.642	0.73	0.001
Foot length (mm)	75.54	6.495		

SD: Standard deviation

DISCUSSION

The majority of newborn mortality, specifically 75%, occur during the initial neonatal period, while 25–45% of these deaths happen within the first 24 h of life. The majority of newborn deaths occur in underdeveloped nations. India accounts for 20% of global births and 25% of global newborn deaths. Neonatal outcome is mostly determined by birth weight (BW), that is the highest significant determinant.[10] Around 80% of neonatal mortality in both industrialized and developing nations are caused by factors such as LBW, preterm, infection, birth asphyxia, and delivery trauma. In India, the percentage of babies with LBW is 30%, which is significantly higher compared to the 5–7% rate observed in western countries.[2]

In our nation, the majority (70–80%) of deliveries occur at the peripheral level, where accurately measuring weight and determining gestational age is challenging due to the lack of weighing machines and skilled workers. These variables contribute to the failure of promptly identifying LBW and pre-term infants who need immediate referral to a specialized facility for additional medical attention. Foot length (FL), measuring 13–14 inches, is a simple and efficient measurement that shows a strong relationship with body weight (BW) and can precisely forecast age of gestation.[11] It is a quick measurement that can be easily performed, even on critically unwell neonates in a level III neonatal intensive care unit. The FL is a straightforward and easily obtainable anthropometric measure that is highly dependable. It is beneficial for assessing the body weight (BW) and gestational age in both preterm and term infants.

Table 4: Association of foot length and gestational age

Parameters	Variables	Values		Correlation coefficient (r value)	*P*-value
		Mean	SD		
Pre-term babies	GA (weeks)	34.641	2.148	0.76	0.001
	Foot length (mm)	69.485	6.421		
Term babies	GA (weeks)	38.214	1.547	0.54	0.001
	Foot length (mm)	77.754	4.508		
Post-term babies	GA (weeks)	42.317	2.074	0.77	0.001
	Foot length (mm)	73.147	5.417		
SGA	GA (weeks)	37.221	2.917	0.81	0.001
	Foot length (mm)	74.579	6.271		
AGA	GA (weeks)	36.589	2.784	0.76	0.001
	Foot length (mm)	74.778	6.224		
LGA	GA (weeks)	35.417	2.472	0.75	0.001
	Foot length (mm)	73.571	6.775		

SGA: Small for gestational age, AGA: Appropriate for gestational age, LGA: Large for gestational age

The current study revealed a significant positive relationship between gestational age (GA) and fetal length (FL). For preterm babies, the mean GA was 34.641 weeks (SD = 2.148), with a r = 0.76 (P = 0.001). Term babies had a GA of 38.214 weeks (SD = 1.547) and a r = 0.54. Post-term babies had a GA of 35.317 weeks (SD = 2.074) and a r = 0.77. These findings are similar with previous studies conducted by James *et al*.,[12] Gohil *et al*.,[13] and Kim and Moon[14] with a correlation coefficient (r value) of 0.79. In addition, the findings also are in line with the research carried out by Wyk and Smith[15] which had a r = 0.919. Similarly, the study by Srivastava *et al*.[16] had a r = 0.87, Madhulika *et al*.[17] had a r = 0.94, and Hadush *et al*.[18] had a r = 0.85, all of which are in line with our study.

The current study investigated the association between foot length at birth and the duration of pregnancy. The results revealed that out of the 230 infants, 19.56% were categorised as SGA, while the rest (70.86%) fell within the normal range. A total of 9.56% of the babies were categorized as LGA, suggesting a notable percentage that surpassed the established weight or size criteria. This data is highly similar to the findings of Rakkappan and Kuppusamy[19] which reported 85% of newborns as AGA, 14.3% as SGA, and 0.6% as LGA. It is similarly identical with the results of Shahhu *et al*.,[20] which showed 84.8% AGA, 13.2% SGA, and 2.1% LGA. The number of SGA newborns in this region is relatively higher compared to other locations. In 1920, Streeter[21] discovered that there is a clear correlation between the foetal foot length and the gestational age. They also found that the measurement of fetal foot length can be utilized to assess the age of gestation. Subsequently, other researches have been conducted to determine the link between FL and GA.

Among the 230 infants, 120 were males, representing 52.17% of the study. The data reveals a minor prevalence of males in the sample, which aligns along with the results of researches conducted by Tenali and Tenali[22] and Singhal *et al*.[23] The study described above indicates that 53% of the participants were male, while 59% were male in the respective group.

The study examined the socioeconomic condition of babies and found a gradual spread across several strata. Out of the total number of newborns, 15 or 6.52% were from the upper class, 30 or 13.04% were from the upper middle class, and 60 or 26.08% were from the middle class. The most sizable demographics consisted of the lower middle and lower socioeconomic classes. According to the research conducted by Shachi Selvendran *et al*.,[24] 30.50% of the total 61 newborns were from the lower socioeconomic class, whereas 4% of the total eight babies belonged to the upper socioeconomic class, which aligns with our own study findings.

The current study revealed a notable disparity in the weight at birth of newborns. Out of the 230 participants, 41.30% had a weight below 2500 g, while 58.69% had a weight above 2500 g. This raises concerns about the occurrence of premature births, which is unswerving with the findings of Akukwu Hossain *et al*.[25] in Nigeria, where birth weights ranged from 0.85 kg to 4.5 kg, and Gowri and Shah[26] who reported a range of 0.7 kg to 3.8 kg.

The study conducted by Resu[27] examined the relationship amid length of foot and age of GA. The analysis revealed a significant positive correlation (P = 0.001) with a r = 0.77. On doing a correlation analysis amidthe length of foot and weight at birth, we discovered a significant positive association with a r = 0.74 (P = 0.001). A simple linear regression analysis was conducted to determine the impact of age at GA and birth weight on foot length. The results of our research indicate a strong association between the weight at birth and the length of foot in infants. On average, the birth weight was 2.6154 kg, while the average foot length was 75.54 mm. The presence of a robust positive correlation value of 0.73 suggests a direct relationship between increases in birth weight and increases in foot length. This connection may suggest the existence of underlying biological and developmental processes. Our work aligns with Resu[27] findings regarding the strong positive link between foot length and gestational age (GA) in pre-term, term,

and post-term infants. The association was highest among SGA babies, followed by AGA and LGA babies. These findings emphasize the significance of the gestational age and birth size in regulating the feet length and gestational age.

CONCLUSION

This study has definitively proven a significant and positive relationship between the length of a newborn's foot and the duration of pregnancy, highlighting the possibility of employing foot length as a straightforward and dependable indication for evaluating the maturity of a newborn without any need for invasive procedures. The results indicate that both premature and full-term infants have different foot length assessments that are strongly associated with their gestational ages. This provides a useful approach for evaluating the fetal maturity of babies in clinical environments. This correlation was notably strong across various classifications of gestational age, including SGA, AGA, and LGA babies, with the highest correlation observed in SGA newborns. The study's implications extend beyond clinical assessments, providing a valuable tool for regions lacking advanced diagnostic facilities. It proposes an accessible means to improve the accuracy of neonatal care and intervention strategies, particularly in low-resource environments. This research enriches the existing body of knowledge on neonatal care, accentuates the importance of integrating simple, evidence-based practices in pediatrics to enhance the outcomes of newborn well-being and growth.

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