Original Article

Newborn Foot Length Measurement to Identify High-risk Neonate

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Abstract

Introduction: To study the correlation between foot length (FL) and other variables such as birth weight (BW), gestational age, chest circumference (CC), and head circumference and to determine the utility of using FL as a screening tool to identify small babies in need of extra care.

Materials and Methods: It is a cross-sectional descriptive study of 1000 neonates conducted in the Government Rural Medical College Hospital. The FL, head and CC, BW, and gestational age of study population were collected using standard methods. Correlation of FL with other anthropometric measurements of these groups was statistically analyzed using Statistical Package for Social Studies version 16 software.

Results: The study group included 53.7% of male and 46.3% female babies. There were 81.4% term and 18.6% preterm babies. In this study group, there were 85.1%, 14.3%, and 0.6% of appropriate for gestational age (AGA), small for gestational age (SGA), and large for gestational age (LGA) babies, respectively. The mean FL for term babies observed in this study is 6.91 cm with the standard deviation of 0.44. The mean FL for preterm babies is 5.94 cm with a standard deviation of 0.43. Statistically by performing Scheffe's multiple comparison test the FL was found to be significantly different in AGA, SGA, and LGA babies. Statistically by performing Pearson correlation coefficient, the FL correlated significantly with gestational age, head and CC, and BW. By performing the regression equation, FL has the potential to predict the gestational age. The mean FL for gestational ages of 26, 28, 30, 32, 34, 36, 38, 40, and 42 weeks were 4.6, 5.26, 5.5, 5.52, 6.11, 6.58, 6.98, 7.45, and 8.15 cm, respectively.

Conclusion: FL is a simple and more reliable anthropometric measurement to assess the BW and gestational age in newborn babies and can be used to screen prematurity and SGA babies in need for care.

Key words: Foot length, Low birth weight, Neonatal mortality, Preterm baby

INTRODUCTION

Neonatal period is a more vulnerable period of life, and its death accounts for 60% of all infant mortality rate and 40% of all deaths of under-five children.

Global infant death rate is approximately 8 million/year, of which 4 million deaths occur during the neonatal period. Most neonatal deaths - 75% occur in the early neonatal period and 25% during first 24 h of life. Most of the neonatal deaths occur in developing countries. India contributes 20% of global birth and 25% of global neonatal death.

Birth weight (BW) is the single most important factor for the outcome of neonate. Approximately 80% of all neonate deaths are due to low birth weight (LBW) in both developed and developing countries. In India, 30% babies are LBW as against to about 5-7% in western countries and also is in second place in South Asia region.[1-7]

In our country, 70-80% of deliveries are conducted at peripheral level, where taking accurate weight and assessment of gestational age is very difficult because of non-availability of weighing machine and trained personnel.

All these factors lead to failure of early identification of LBW and preterm babies who require urgent referral to higher center for extra care.[8-14]

Because of above reasons, varying number of studies were conducted to find out the alternate suitable measurement for BW and gestational age. These should be more reliable, be simple, good correlation with gestational age and BW in all groups of newborn.

This measurement should be less prone for measurement error and be conducted by even an untrained person or inexperienced health care staff. The technique should have minimal inter- and intra-observer variability.

Foot length (FL) is one of the measurements, which can be measured very easily, bears good correlation with BW, good predictor of gestational age, rapid to perform, can be measured in critically ill neonates and level III neonatal intensive care unit (NICU).[15-20]

The foot of the newborn is easily accessible to measure their length in LBW, very LBW, and premature babies. There is a practical barrier to measuring all anthropometric parameters of newborn who are on ventilator, require minimum handling, and nursed in incubator, particularly daily measurement of weight is difficult.

The FL can be used as a proxy measure in all sick newborn babies receiving NICU care who are inaccessible to measure crown-heel length and body weight, the measurement of FL guides to calculate drug dosages and fluid requirement. The FL can predict the prematurity and LBW.

FL is a very simple, easily accessible, and more reliable anthropometric variable to assess the BW and gestational age in preterm neonate and term neonates. For measuring the newborn FL does not require any special training and equipment.[21-27]

Aim of Study
To study the relationship between the FL and gestational age in preterm and term neonates.

To determine the utility of using FL as a screening tool to identify small babies (LBW/premature) in need of extra care.

To study the correlation between FL and other variables (BW, gestational age, chest circumference (CC), and head circumference HC) among small for gestational age (SGA), appropriate for gestational age (AGA), and large for gestational age (LGA).

MATERIALS AND METHODS

Place of Study
Government Rural Medical College Hospital, South Tamil Nadu.

Inclusion Criteria
All live neonates born in the hospital during the study period.

Exclusion Criteria
All babies with lower limb congenital anomalies.

Instrument Used
A. ISI certified sliding calipers for FL measurement
B. Electronic weighing scale for BW measurement
C. Flexible and non-stretchable measuring tape for head and CC.

Data Collection
The following data were collected for all the babies:
a. BW
b. FL
c. Gestational age
d. HC
e. CC.

Study Duration
Target of 1000 consecutive live-born babies in our hospital over 1 year.

Study Design
Cross-sectional study done on the 1st day of life.

Limitations of the Study
The study population may not be representative of the entire community and was derived from a convenient sample of neonates from a referral hospital.

Statistical Methods Used
The data collected was analyzed using Statistical Package for Social Studies - Version 16. The correlation between FL and parameters such as gestational age, BW, HC, and CC was analyzed by applying correlation and regression analysis. Regression analysis was derived to predict gestational age from FL in babies.

RESULTS AND ANALYSIS

In this study, results are tabulated and analysis done based on those tables.

Table 1 shows the mean anthropometric measurements of FL, HC, CC, and BW for various gestational ages observed in the study.

Table 1: Mean foot length, HC, CC, and birth weight for babies of various gestational ages

Gest age weeks	FL (cm)		HC (cm)		CC (cm)		BW (cm)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
26	4.5-4.7	4.6	21-24	22.33	17-20	18.33	0.5-0.7	0.6
28	4.9-6.0	5.26	23-29	25.16	19-24	21.00	0.7-1.25	0.9
30	5.2-5.9	5.5	25-29	27.14	22-26	23.42	1-1.6	1.4
32	5-6.2	5.52	23-31	27.18	20-32	24.13	1-1.9	1.41
34	5.3-6.9	6.11	26-32.5	30.05	21-29	26.95	1.2-2.4	2.03
36	6.0-7.5	6.58	29-34.5	31.67	18.5-28.5	28.98	1.7-3.5	2.56
38	6.3-7.9	6.98	30-35	32.44	26-38.5	29.00	2.1-3.75	2.92
40	6.7-8.2	7.45	32-36	33.36	29-33	29.68	2.7-4.2	3.44
42	8.0-8.3	8.15	35-35.5	35.00	30-30.5	30.00	4-4.25	4.12

FL: Foot length, HC: Head circumference, CC: Chest circumference, BW: Birth weight

Table 2 depicts the range and mean of FL in various groups of babies. As expected the FL increases with increasing gestational age.

Table 3 shows the descriptive statistics of the selected anthropometric variables of the newborn babies. The median FL at birth has been 6.8 cm, which implies that 50% of the babies have FL above this value and 50% of the babies have below this value. The minimum value has been 6.40 cm, and the maximum value has been 8.30 cm. The average FL of the newborn babies has been 6.73 cm with the standard deviation of 0.58 cm. The 95% confidence limit for mean with lower and upper limits infers that 100 times such a study with a sample of 1000 babies has been carried out; in 95% of the studies, the mean value would have been between 6.69 cm and 6.77 cm.

The mean HC of the newborn babies has been 31.74 cm with the standard deviation of 1.76 cm. The minimum and maximum values observed in this study have been 21 cm and 36 cm, respectively.

The mean CC value obtained in this study has been 28.32 cm with the standard deviation of 1.84 cm. The minimum and maximum values have been 17 cm and 38.5 cm, respectively.

The median BW of the 1000 babies has been 2.70 kg. The mean BW has been 2.69 kg with the standard deviation of 0.56 kg. Most of the Babies BW would have been around 2.70 kg. The minimum BW obtained has been 0.5 kg, and the maximum BW has been 4.25 kg.

Table 4 shows the mean comparison of the selected anthropometric variables of the newborns by their maturity status. Student's t-test has been applied to compare the mean values. The average FL for the term babies has been 6.91 cm for the male babies, whereas the mean FL for the preterm babies has been 5.94 cm. The significant P value of the student t-test infers that term babies are having higher FL than preterm babies as expected.

Table 2: Foot length for various groups of babies

Maturity and gestational age	Number of babies	Range	Mean±standard deviation
Preterm SGA	92	4.5-6.9	5.7663±0.5041
Preterm AGA	94	5.5-7.0	6.1191±0.2428
Term SGA	51	6.0-7.2	6.3156±0.2043
Term AGA	757	6.0-8.0	6.9519±0.3541
Term LGA	6	8.0-8.3	8.1166±0.1329

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

Similarly, the other three variable's significant P value infers that term babies are having comparatively higher mean values than preterm babies.

Table 5 shows the mean wise comparison of the selected anthropometric variables by their weight for gestational age status. The one-way analysis of variance (ANOVA) test has been applied to compare the three categories, though the category LGA has only 6 babies. Hence, the interpretation was made with little care. If one-way ANOVA test is significant, Scheffe's multiple comparison test was applied to compare which of the groups are statistically different.

For all the four variables, the ANOVA test has been significant at $P < 0.001$ level. The mean anthropometric values have been statistically different for the three groups. To know which of the groups are different, Scheffe's multiple comparison test has been applied and the results are shown in Table 5.

Table 6 shows the Scheffe's multiple comparison test for the three categories of the selected anthropometric variables. All the comparisons have been statistically significant. This clearly indicates that the mean values for all the four variables have been higher for babies with LGA, and the mean values for all the four variables have been lower for babies with SGA, and for the babies with appropriate weight for gestational age has been in between small and LGA babies.

Table 3: Descriptive statistics of the anthropometric variables of the study population

Variables	Number of newborn babies	Minimum	Maximum	Median	Mean±standard deviation	95% confidence limit for mean	
						Lower limit	Upper limit
Foot length (cm)	1000	4.50	8.30	6.80	6.73±0.58	6.69	6.77
Head circumference (cm)	1000	21.00	36.00	32.00	31.74±1.76	31.63	31.85
Chest circumference (cm)	1000	17.0	38.5	28.50	28.32±1.84	28.20	28.43
Birth weight (kg)	1000	0.50	4.25	2.70	2.69±0.56	2.65	2.73

Table 4: Mean comparison of the selected anthropometric variables of the newborn babies by their maturity status

Variables	Maturity status	Number of babies	Mean	SD	t test value	P value
Foot length (cm)	Term	814	6.91	0.44	26.804	<0.001
	Preterm	186	5.94	0.43		
Head circumference (cm)	Term	814	32.33	0.97	30.496	<0.001
	Preterm	186	29.18	2.12		
Chest circumference (cm)	Term	814	28.84	1.13	23.099	<0.001
	Preterm	186	26.04	2.53		
Birth weight (kg)	Term	814	2.89	0.38	32.945	<0.001
	Preterm	186	1.83	0.42		

SD: Stasndard deviation

Table 5: Mean wise comparison of the selected anthropometric variables of the newborn babies by their weight for gestational age

Variables	Weight for gestational age	Number of babies	Mean±standard deviation	ANOVA test F value	P value
Foot length (cm)	Appropriate	851	6.85±0.48	234.471	<0.001
	Small	143	5.96±0.49		
	Large	6	8.11±0.13		
Head circumference (cm)	Appropriate	851	32.13±1.19	251.611	<0.001
	Small	143	29.29±2.44		
	Large	6	34.83±0.51		
Chest circumference (cm)	Appropriate	851	28.68±1.31	176.900	<0.001
	Small	143	26.04±2.70		
	Large	6	30.91±1.42		
Birth weight (kg)	Appropriate	851	2.83±0.42	358.081	<0.001
	Small	143	1.82±0.47		
	Large	6	4.07±0.11		

Table 6: Significance level of mean difference between three categories of weight for gestational age for each selected anthropometric variable

Variables	Group A	Group B	Mean difference	Scheffe's multiple comparison test – P value
Foot length (cm)	Appropriate	Small	0.89	<0.001
	Appropriate	Large	−1.26	<0.001
	Small	Large	−2.15	<0.001
Head circumference (cm)	Appropriate	Small	2.83	<0.001
	Appropriate	Large	−2.69	<0.001
	Small	Large	−5.53	<0.001
Chest circumference (cm)	Appropriate	Small	2.64	<0.001
	Appropriate	Large	−2.22	<0.001
	Small	Large	−4.87	<0.001
Birth weight (kg)	Appropriate	Small	1.00	<0.001
	Appropriate	Large	−1.24	<0.001
	Small	Large	−2.24	<0.001

Table 7: Pearson correlation coefficient between foot length and head circumference, chest circumference, birth weight, and gestational age for the new born babies

Variable	Foot length	Gestational age	Head circumference	Chest circumference	Birth weight
Overall	*r* value	0.807**	0.850**	0.741**	0.918**
Sex					
Male	*r* value	0.766**	0.815**	0.695**	0.881**
Female	*r* value	0.860**	0.896**	0.799**	0.968**
Maturity status					
Term	*r* value	0.614**	0.734**	0.554**	0.853**
Preterm	*r* value	0.756**	0.893**	0.790**	0.872**
Weight for gestational age					
Appropriate	*r* value	0.717**	0.0783**	0.611**	0.874**
Small	*r* value	0.824**	0.907**	0.845**	0.903**

Due to small sample size, the correlation coefficient between the foot length and other variables are not calculated for the babies classified as "large for gestational age."
**$P<0.001$

Table 7 shows the Pearson correlation coefficient value between the FL and the selected variables. The correlation coefficient has been calculated for the overall sample, and separately for each characteristic of the newborn babies. Further, the significance level of the correlation coefficient is also noted in the table. The FL of the babies highly correlated with their gestational age, HC, CC, and BW. All the correlations are significant at $P < 0.001$ level.

Table 8 shows the prediction of the gestational age based on FL of the newborn babies. Linear regression analysis has been applied to predict the gestational age of the babies by their FL. For the overall sample, the gestational age has been expressed as an equation of 15.343 + 3.183 (FL).

Here, 3.183 indicates the slope of the equation and 15.343 is constant. The slope value infers that as 1 cm increase in the FL means 3.1 weeks increase in the gestational age. The R^2 value infers that the regression equation correctly predicts the gestational age in 65% of the times.

Regression equation has been applied for separately for each category, and the results are shown in Table 8. In all the regression equation, the R^2 value infers that FL has been moderately influence on the prediction of the gestational age in weeks.

DISCUSSION

The reduction of neonatal mortality in developing countries like India requires the simple measurement to early identification of the preterm and LBW babies. At birth CC, HC and BW are routinely measured. In India, non-availability of equipment to measure the above parameters and given logistic constraints of care during delivery, the imperative need to identify the high-risk newborn babies, there is a need of appropriate, alternate parameter, which can be easily measurable and not sophisticated one. The

Table 8: Predicting gestational age using foot length of the newborn babies

Variable	Regression equation	R^2 value
Overall	GA=15.343+3.183 (FL)	0.652
Sex		
Male	GA=17.465+2.873 (FL)	0.586
Female	GA=12.440+3.614 (FL)	0.739
Maturity status		
Term	GA=23.368+2.057 (FL)	0.376
Preterm	GA=15.050+3.056 (FL)	0.572
Weight for gestational age		
Appropriate	GA=17.567+2.867 (FL)	0.514
Small	GA=10.671+3.913 (FL)	0.679
Large	Since only 6 cases equation is not fitted	

FL: Foot length

FL is a one of the measurements which can be measured easily even in very sick babies.

This study has done to find out the correlation of FL with other anthropometrics measurements in newborn babies and the use of FL as a proxy measurement for estimation BW and gestational age. To determine the utility of using FL as a screening tool to identify small babies (LBW/premature) in need of extra care.

In this study, 1000 newborn babies were recruited, and their anthropometric measurements were recorded. Among them, 53.7% are male babies and 46.3% are female babies. These values are nearly close to the results in the Shambu *et al.* study showed 52.4% males, 47.6% females. In Kulkarni and Rajendran[20] study, males are 56% and females are 44%, respectively.

In this study, term babies are 81.4% and preterm babies are 18.6%, which is comparable to Kulkarni and Rajendran study showed 82.4% term and 17.5% preterm. The study conducted by Gohil *et al.*[22] showed term babies are 89.5% and preterm babies are 10.5%.

In this study, SGA babies are 14.3%, AGA are 85.1%, and LGA are 0.6%. This study is comparable with Shambu *et al.* which showed SGA 13.2%, AGA 84.8%, and LGA 2.1%.

BW of 1000 newborn babies in this study ranges from 0.5 to 4.25 kg with the mean of 2.69. This is comparable to the study done by Shambu *et al.* BW range of 0.85-4.3 kg with the mean of 2.931 kg. Huque and Hussain[13] study the mean BW was 2.679 kg which is comparable to this study.

As the LGA group was small, statistical analysis was not possible. This was also the case in many studies such as Kulkarni and Rajendran.

In this study of 1000 neonates, the FL ranged from 4.5 cm to 9.9 cm. The FL increased with increasing gestational age. The mean FL of term babies was 6.91 cm with a standard deviation of 0.44. The confidence limit for the mean FL in the term babies is 6.88 in the lower limit and 6.94 in upper limit. The mean FL in preterm babies is 5.94 with the standard deviation of 0.43. The confidence limit for the preterm babies is 5.88 in lower limit and 6.00 in upper limit.

The mean FL varied in all the above studies. Although there is the positive linear relation between FL and gestational in all these studies. This implies the need for having standard for each ethnic for differently, the mean FL of our study closely correlated with the Kulkarni and Rajendran study.

In this study, the mean FL for gestational ages of 26, 28, 30, 32, 34, 36, 38, 40, and 42 weeks were found to be 4.6, 5.26, 5.5, 5.52, 6.11, 6.58, 6.98, 7.45, and 8.15 cm, respectively. (Table 9 and Figure 1)

CONCLUSION

In the ever expanding field of pediatrics, the pediatrician's quest for innovations and inventions for the betterment of children continues at a rapid pace. One such innovation is the development of newer anthropometric measures which will guide us in assessing growth and development of children.

This study evaluated the measurement of FL as an important anthropometric measure in neonates. The study group included 1000 neonates and was diverse in sex, maturity, and BW. The FL was compared to other anthropometric measures.

The FL correlated significantly with gestational age, head and CC, and BW across all the subgroups.

This study also demonstrated the capability of FL to predict gestational age by regression equation and thereby

Table 9: Comparison of foot length in various studies

Study	Foot length range in term babies (cm)
Present study	6.4-8.3
Kulkarni and Rajendran	6.6-9-7.58
Gohil *et al.*	7.6±0.33
Shambu *et al.*	8.0±0.28
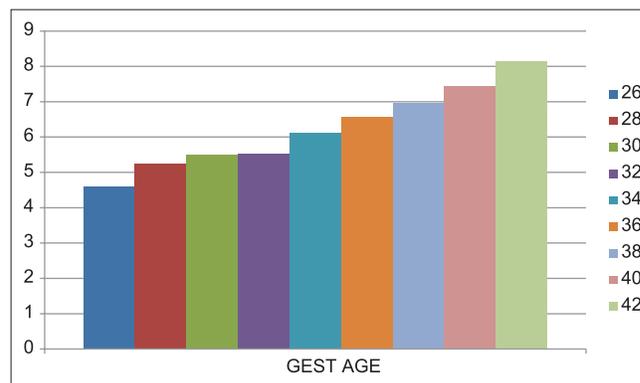
Figure 1: Mean foot length, head circumference, chest circumference, and birth weight for babies of various gestational ages

identifying high-risk babies with prematurity or SGA in need for care.

This study also yielded mean FL values for gestational ages from 26 to 42 weeks.

To conclude, this study has demonstrated that FL can emerge as an important anthropometric measurement in neonates and can be used to screen prematurity and SGA babies in need for care. However, multicentric studies across the world are needed to evaluate the significance of FL in various ethnic and racial groups.

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