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Original Article

A Prospective Observational Study to Determine a Correlation between Foot Length and Gestational Maturity in Neonates Born at a Tertiary Care Hospital in South India

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Abstract

Background: Accurate assessment of gestation maturity is not possible in all newborn babies especially when they are sick and when intensive care support is needed. The aim was to study correlation of foot length (FL) and other anthropometric measurement with gestational maturity in neonates.

Materials and Methods: Prospective observational study was done in 1000 babies born at Kovai Medical Center and Hospital, Coimbatore, Tamil Nadu, India, from October 2019 to May 2020. FL at birth was measured using sliding caliper from the posterior most prominence of foot to the tip of the longest toe on right foot. Gestational assessment was done using modified Ballard's scoring on day 1. Linear regression analysis was done to investigate the relation of FL to gestational age (GA), birth weight (BW), head circumference (HC), chest circumference (CC), and crown heel length (CHL).

Results: About 52.2% were male and 47.8% were female babies. Of the 1000 newborns, preterm babies were 209 (20.9%), term babies were 775 (77.5%), and post-term babies were 16 (1.6%). The mean FL was 7.43 cm with a range of 4.30–8.79 cm. FL correlated significantly ($P < 0.05$) with GA, BW, HC, CC, and CHL in preterm small for GA (SGA), preterm appropriate for GA (AGA), preterm large for GA (LGA), term AGA, and term LGA. The correlation coefficient of FL with GA was maximum in preterm SGA (r = 0.934) and preterm AGA groups (r = 0.902), followed by preterm LGA (r = 0.832), term AGA (r = 0.341), and term LGA (r = 0.246). In term SGA, FL correlated with BW, HC, and CHL but not with GA and CC, while in post-term AGA, FL only correlated with BW.

Conclusions: FL correlated significantly with GA and other anthropometric parameters in preterm babies and in term AGA and LGA babies.

Key words: Birth weight, Crown heel length, Foot length, Gestational age

INTRODUCTION

Neonatal period is the most vulnerable period of life.[1] Although the global number of newborn deaths declined from 5 million in 1990 to 2.4 million in 2019, children face the greatest risk of death in their first 28 days.[2] The main causes for neonatal deaths are prematurity, low-birth-weight (LBW), infections, asphyxia, and birth trauma, accounting for 80% of neonatal deaths.[1]

Prematurity is a major determinant of neonatal survival.[3] Globally, about one-sixth of all newborns are BW (<2500 g), which is single most important underlying risk factor for neonatal deaths.[4-6] Only about half of the newborns are weighed at birth and further for a smaller proportion of them the gestational age (GA) is known.[4,7] Identifying these LBW and preterm babies and referring them to higher centers for effective interventions will help in decreasing neonatal mortality and morbidity.[1]

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Conventionally, GA is calculated by Naegele's formula and antenatal ultra-sonography (USG), or using Ballard Scoring in neonates. In rural settings with low literacy levels, application of Naegele's formula and non-availability of antenatal USG check-up are limiting factors. Application of ballard scoring requires the expertise of a pediatrician who may not be available in remote area. Moreover, it cannot be used in asphyxiated neonates.

All these factors thus underline the importance of early identification and reference to higher center of preterm babies at the rural setup, where most of the deliveries are conducted at home by untrained relatives, traditional birth attendants, and dais having no proper neonatal medical care facilities.[8]

Parameters such as BW, crown-heel length (CHL), and head circumference (HC) are commonly used as predictors of growth and maturity in neonates. Anthropometric measurements such as BW and length are significantly affected by changes in water, carbohydrate, fat, protein, and mineral levels. Although HC reflects brain growth, the effect of head sparing during malnutrition may result in an underestimation of growth restriction.[9]

The identification and evaluation of low-cost tools to accurately identify small newborns in primary healthcare and community settings have been ranked as the number one research priority to reduce global mortality from prematurity and LBW.[10] Since decades, attempts have been made to find an alternative for GA assessment in newborns. These alternative measurements should be reliable, have a close correlation with GA, can be performed even by inexperienced medical personnel and have very little intra- and inter-observer variability.[8]

New born foot length (FL) is an easy, quick, and efficient measurement for preterm, critically ill newborns. This measurement technique is not influenced by either subcutaneous fat or biological sex.[11] It has also been stated that FL is the least affected anthropometric measurement in intra uterine growth restricted babies.[9] FL is one such parameter which can be measured easily in preterm and sick neonates without disturbing the baby.[8]

The foot of the new born is usually readily accessible for measurement, even in incubators.[12]

This study is being done to find a correlation between FL, gestational maturity, and other anthropometric measurements.

Aims and Objectives

The aim of the study was to a prospective observational study to determine a correlation between FL and gestational maturity in neonates born at a tertiary care hospital in South India.

1. To study the correlation of FL and GA among preterm, term, and post-term neonates
2. To study the correlation between FL and other variables (BW, GA, HC, chest circumference [CC], and CHL) among small for GA (SGA), appropriate for GA (AGA), and large for GA (LGA) newborns
3. To study whether FL can be used as a proxy measurement to BW and GA assessment in newborns
4. To study whether FL correlates with the GA assessment using new ballard score (NBS) and with that using last menstrual period (LMP) method and with ultrasound assessment.

MATERIALS AND METHODS

Study Design

This was a prospective observational study.

Study Area

This study was conducted at the Department of Paediatrics, Kovai Medical Center and Hospital, Coimbatore.

Study Period

The study period was from October 2019 to May 2020.

Inclusion Criteria

All live newborns of different GAs born at Kovai Medical center and hospital, Coimbatore within 72 hours of birth were included in the study.

Exclusion Criteria

Babies who were having skeletal deformities of the foot, foot edema, who had perinatal asphyxia, who are more than 72 hours of age, who are born elsewhere, having major congenital anomalies, whose mother is unaware of LMP or when USG is not available, and in whose parents refused to provide informed consent were excluded from the study.

Study Details/Methodology

The study was started after getting institutional scientific and ethical committee clearance. 1000 live newborn babies satisfying the inclusion criteria were recruited for the study.

Parents were approached following the birth of their child, and the study was explained in their local language. Patient information sheet was also provided. Following written informed consent (or for those illiterate, a witnessed thumb print was provided), a data collection form was completed by interview with the parent/guardian and a review of the medical records. Consent material also was made available in the local language. The date of LMP was sourced from the mother to estimate expected date of delivery and GA

of the newborn. Medical records were reviewed for early ultrasound findings and estimated date of delivery. If these were not recorded, the information was requested from the mother.

Data were collected using standard pro forma meeting the objectives of the study

a. GA assessment was done using modified NBS
b. FL was being measured using sliding which is having an accuracy of a millimeter. FL was measured from posterior most prominence of foot to the tip of the longest toe of the right foot
c. HC and CC were measured using flexible, non-stretchable fiber measuring tape as per standard protocol
d. CHL was measured using a standard infantometer using an assistant's help
e. Weight of the baby was measured using electronic weighing scale with an accuracy of ±10 g. All the dress of baby was removed before weighing.

Babies were grouped into preterm, term, and post-term categories. Babies <37 weeks of gestation were counted in the preterm group. Babies ≥42 weeks of gestation were counted in the post-term age group. All the three groups of babies were categorized into SGA, AGA, and LGA groups. This classification was done using Lubchenco intrauterine growth curve.

Statistical Analysis

Data entry was done in Microsoft Excel spread sheet and the statistical analysis was carried out using the SPSS software version 20.0 for windows. Descriptive analysis was done to exhibit the frequency of observations, mean, and standard deviation. Chi-square analysis was used to test the significant association on target variable by substantial variable. ANOVA was used to test the significant difference between three or more groups on selected variables. Regression analysis was used for estimating relationship between a dependent variable and one or more independent variables. $P < 0.05$ was considered as statistically significant.

RESULTS

The study included 1000 newborns of which 522 (52.2%) were male and 478 (47.8%) were females. Out of 1000 babies, 775 (77.5%) were term, out of which 13 (1.3%) were term SGA, 700 (70%) were term AGA, and 62 (6.2%) were term LGA babies. A total of 209 (20.9%) were preterm, of which 35 (3.5%) were preterm SGA, 166 (16.6%) were preterm AGA, and 8 (0.8%) were preterm LGA babies. A total of 16 babies were post-term, of which 15 (1.5%) were post term AGA and 1 (0.1%) was post term LGA. There were no babies in post-term SGA group.

Of the 1000 neonates studied, the mean FL was 7.43 cm with a range of 4.30–8.79 cm and standard deviation of 0.59. The preterm SGA, AGA, and LGA had a mean FL of 6.03, 6.78 and 7.63 cm, respectively. The mean FL for term SGA, AGA, and LGA were 7.04, 7.61, and 8.02 cm, respectively. The mean FL for post-term AGA and LGA were 7.60 and 8.48 cm, respectively [Table 1].

Overall mean HC was 33.43 cm. The minimum and maximum HC of preterm neonates were 24 cm and 35.5 cm, term neonates was 30.5 cm and 36 cm and for post-term neonates was 33.5 cm and 35 cm, respectively. The mean HC of pre-term SGA, AGA, and LGA was 29.23 cm, 31.51 cm, and 33.94 cm, while for term SGA, AGA, and LGA was 32.77 cm, 33.98 cm, and 34.76 cm, and it was 34.07 cm in post-term AGA and 34.5 in post-term LGA group, respectively [Table 1].

Minimum and maximum CC in preterm babies were 23 cm and 33.5 cm, term was 30 cm and 34.5 cm and post-term was 31 cm and 34 cm. Mean CC in pre-term SGA, AGA, and LGA group was 27.80 cm, 30.05 cm, and 32.31 cm, while for term SGA, AGA, and LGA babies was 31.12 cm, 32.40 cm, and 33.22 cm and the values where 32.43 cm and 33.50 cm in post-term AGA and post-term LGA groups, respectively. Overall, mean CC was 31.88 cm [Table 1].

Preterm babies had a maximum CHL of 52 cm and minimum of 33 cm, for term it was 53 cm and 45 cm and for post-term 52 cm and 49 cm, respectively. The mean CHL of preterm SGA, AGA, and LGA was 42.27 cm, 46.30 cm, and 50.38 cm, for term SGA, AGA, and LGA was 48.38 cm, 50.24 cm, and 51.71 cm, while in post-term AGA and LGA it was 50.47 cm and 52 cm, respectively. Overall mean CHL was 49.38 cm [Table 1].

In the study group, 801 (80.1%) babies had normal BW, 140 (14%) were low BW, 27 (2.7%) very low BW (VLBW), and 13 (1.3%) extreme low BW while 19 (1.9%) had macrosomia. Mean BW of babies in the study was 2898.76 grams. Lowest and highest BW recorded were 500 g and 4590 g, respectively [Table 1].

FL correlated with GA, BW, HC, CC, and CHL in preterm SGA, preterm AGA, preterm LGA, term AGA, and term LGA babies. In term SGA babies, FL correlated with BW, HC, and with CHL only and in post-term AGA babies, FL only correlated with BW. The correlation coefficient of FL with GA was maximum in preterm SGA ($r = 0.934$) and pre-term AGA groups ($r = 0.902$) followed by pre-term LGA ($r = 0.832$), term AGA ($r = 0.341$), and term LGA ($r = 0.246$) [Tables 2 and 3, Figures 1-7].

Table 1: General data from the study

	No	FL (cm)		HC (cm)		CC (cm)		CHL (cm)		BW (grams)	
		Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Pre-term SGA	35	4.3–7.33	6.03±0.80	24–33	29.23±2.83	23–32	27.80±2.79	33–50	42.27±4.47	500–2100	1529.71±498.97
Pre-term AGA	166	4.5–8	6.78±0.77	24–34.5	31.51±2.67	23–33	30.05±2.68	34–51	46.30±4.24	680–3260	2163.07±620.59
Pre-term LGA	8	6.9–8.09	7.63±0.48	32–35.5	33.94±1.08	31–33.5	32.31±0.96	48–52	50.38±1.41	2160–4030	3288.75±628.80
Term SGA	13	6.6–7.46	7.04±0.22	31.5–33.5	32.77±0.53	30–32.5	31.12±0.74	45–49	48.38±1.19	2010–2460	2266.92±154.40
Term AGA	700	6.57–8.5	7.61±0.24	30.5–36	33.98±0.57	30–34	32.40±0.84	45–53	50.24±0.87	2200–3800	3054.96±309.27
Term LGA	62	7.38–8.79	8.02±0.27	33.5–35.5	34.76±0.48	31–34.5	33.22±0.87	50–53	51.71±1.01	3470–4590	3891.13±246.43
Post-term AGA	15	7.12–8	7.60±0.25	33.5–35	34.07±0.32	31–34	32.43±0.94	49–52	50.47±0.92	2680–3650	3080±296.33
Post-term LGA	1	8.48–8.48	8.48	34.5–34.5	34.5	33.5–33.5	33.50	52–52	52	4450–4450	4450
Total	1000	4.3–8.79	7.43±0.59	24–36	33.45±1.81	23–34.5	31.88±1.86	33–53	49.38±2.92	500–4590	2898.76±625

SGA: Small for gestational age, AGA: Appropriate for gestational age, LGA: Large for gestational age, FL: Foot length, HC: Head circumference, CC: Chest circumference, CHL: Crown heel length, BW: Birth weight

Table 2: Correlation of FL with GA,BW,HC,CC and CHL in various gestational age groups

	Pre-term SGA		Pre-term AGA		Pre-term LGA		Term SGA		Term AGA		Term LGA		Post term AGA	
	r-value	*P*-value	r-value	*P*-value	r-value	*P* -value	r-value	*P* -value	r-value	*P*-value	r-value	*P*-value	r-value	*P*-value
GA	0.934	<0.001	0.902	<0.001	0.832	0.010	–0.120	0.696	0.341	<0.001	0.246	0.049	–	–
BW	0.970	<0.001	0.954	<0.001	0.980	<0.001	0.595	0.032	0.719	<0.001	0.560	<0.001	0.819	<0.001
HC	0.952	<0.001	0.961	<0.001	0.922	0.001	0.555	0.049	0.620	<0.001	0.594	<0.001	0.490	0.064
CC	0.944	<0.001	0.932	<0.001	0.815	0.014	0.210	0.492	0.328	<0.001	0.413	0.001	0.149	0.595
CHL	0.933	<0.001	0.941	<0.001	0.936	0.001	0.800	0.001	0.617	<0.001	0.533	<0.001	0.376	0.168

GA: Gestational age, BW: Birth weight, HC: Head circumference, CC: Chest circumference, CHL: Crown heel length, SGA: Small for GA, AGA: Appropriate for gestational age, LGA: Large for gestational age

Table 3: Relationship of GA with BW and FL

Gestation (number)	Birth weight (g)			Foot length (cm)		
	Min	Max	Mean±SD	Min	Max	Mean±SD
24–25 (1)	500	500	500±0	4.3	4.3	4.3±0
26–27 (8)	610	1000	785±118.92	4.5	4.99	4.71±0.17
28–29 (12)	750	1210	1006.67±181.34	4.82	6.01	5.54±0.48
30–31 (19)	860	1750	1336.84±283.43	4.6	6.4	5.69±0.54
32–33 (27)	1220	2160	1617.41±264.02	5.6	6.93	6.24±0.37
34–35 (52)	1500	3480	2190.96±402.89	5.77	7.7	6.86±0.39
36–37 (142)	1900	4030	2689.15±410.89	6.6	8.4	7.34±0.33
38–39 (457)	2010	4080	3032.06±351.08	6.57	8.79	7.58±0.26
40–41 (264)	2400	4590	3294.20±395.79	6.87	8.5	7.74±0.27
42–43 (18)	2680	4450	3184.44±429.86	7.12	8.48	7.67±0.31
Total (1000)	500	4590	2898.76±625	4.3	8.79	7.43±0.59
P-value			<0.001			<0.001

FL of the baby was found to have significant relationship with GA as follows; GA by LMP: 81.5%, GA by USG: 85.8%, and GA by Ballard: 83.1% [Table 4].

DISCUSSION

The early identification of low BW/preterm babies is an important prerequisite of any initiative to reduce neonatal mortality. There are various measurements in newborns to assess growth. Some of the routine measurements done at birth are HC, CC, CHL, and BW. In many developing countries including India, the equipment required to measure them will not be available in rural or tribal settings or the babies will be sick and minimum handling will be needed to get the maximum information about the anthropometry of the baby. In such cases, FL is an easy tool which can be measured even in sick neonates and requires less handling and is less disturbing to the neonate.

The present study was done to find correlation between FL, gestational maturity/GA, and other anthropometric measurements in neonates, so that FL can be used as a proxy measurement for estimation of GA and BW.

In our study on 1000 neonates, 52.2% (522) were males and 47.8% (478) were females. This was comparable to the study by Gavhane *et al.*[12] where males were 52.5% (420) and females were 47.5% (380) out of 800 newborns studied.

The BW of 1000 neonates ranged from 500 to 4590 g with a mean BW of 2898.76 g, comparable to a study done by Rakkappan and Kuppusamy,[13] where the median BW of 1000 babies was 2700 g with a BW range of 500–4250 g.

In our study, out of 1000 babies studied 18% (180) were low BW of which 1.3% (13) were extremely low birth weight, 2.7% (27) were very low birth weight, and 14% (140) were LBW. In a study done by Gavhane *et al.*,[12] 25.4% (203) constituted LBW out of 800 neonates.

Among 1000 neonates in our study, term AGA, SGA, and LGA were 70% (700), 1.3% (13), and 6.2% (62); preterm

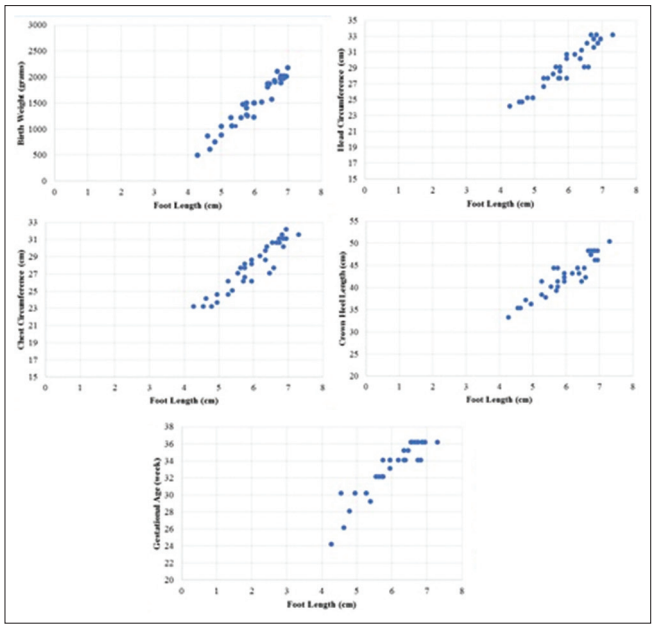

Figure 1: Correlation between foot length and other variables for pre-term small for gestational age

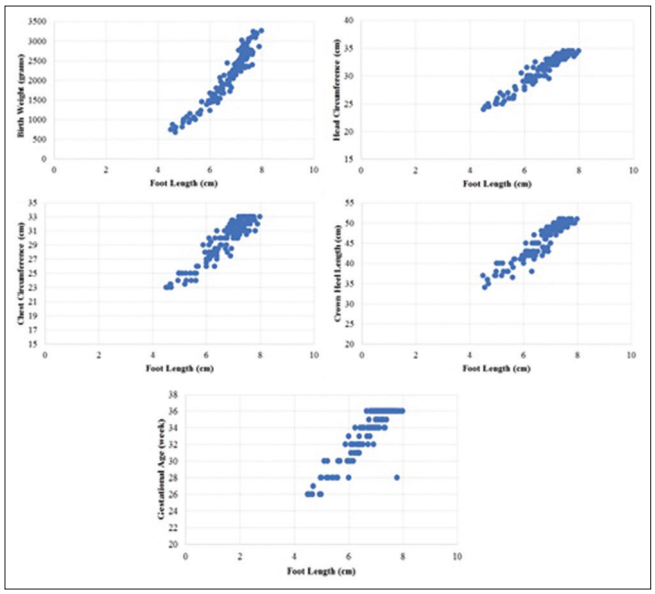

Figure 2: Correlation between foot length and other variables for pre-term appropriate gestational age

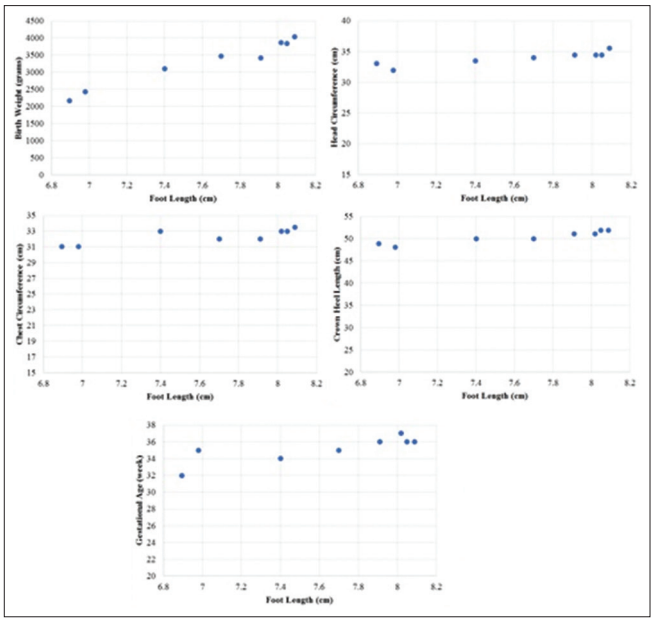

Figure 3: Correlation between foot length and other variables for pre-term large gestational age

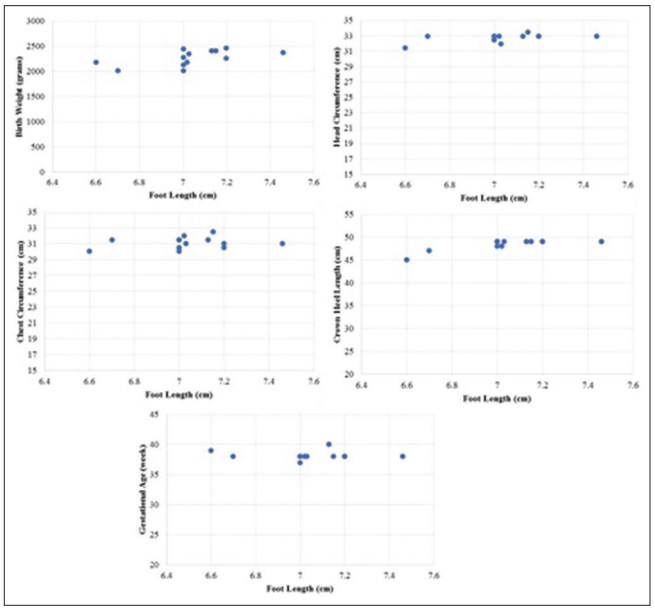

Figure 4: Correlation between foot length and other variables for term small for gestational age

AGA, SGA, and LGA were 16.6% (166), 3.5% (35), and 0.8% (8); and post-term AGA and LGA were 1.5% (15) and 0.1% (1), respectively. There were no babies in post-term SGA group. Out of 1000 neonates, Rakkappan and Kuppusamy[13] study showed 75.7% (757) term AGA, 5.1% (51) term SGA, and 0.6% (6) term LGA babies; pre-term AGA and SGA were 9.4% (94) and 9.2% (92), respectively.

Our FL findings [Table 2] were comparable to the study done by Gavhane *et al.*[12] which showed that the FL of preterm neonates ranged from 4.5 to 7.8 cm with the mean FL of 6.1571 cm and 6.6964 cm for preterm SGA and AGA, respectively. The FL of term neonates ranged from 5.4 to 8.7 cm with a mean FL of 7.0471 cm, 7.5703 cm for term SGA, and AGA respectively and the FL for post-term neonates ranged from 6.7 to 8.8 cm, with a mean FL of 7.5688 cm, 8.0170 cm for post-term SGA and AGA, respectively.

Rakkappan and Kuppusamy[13] in their study showed mean HC of preterm neonates as 29.18 ± 2.12, term neonates

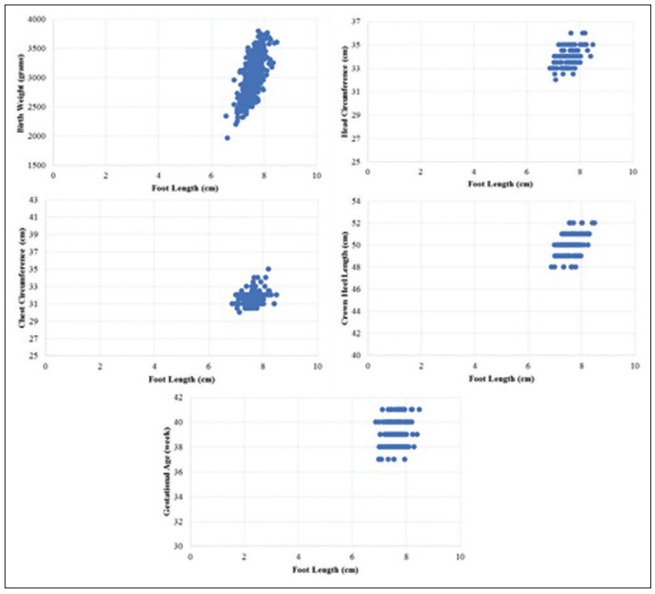

Figure 5: Correlation between foot length and other variables for term appropriate gestational age

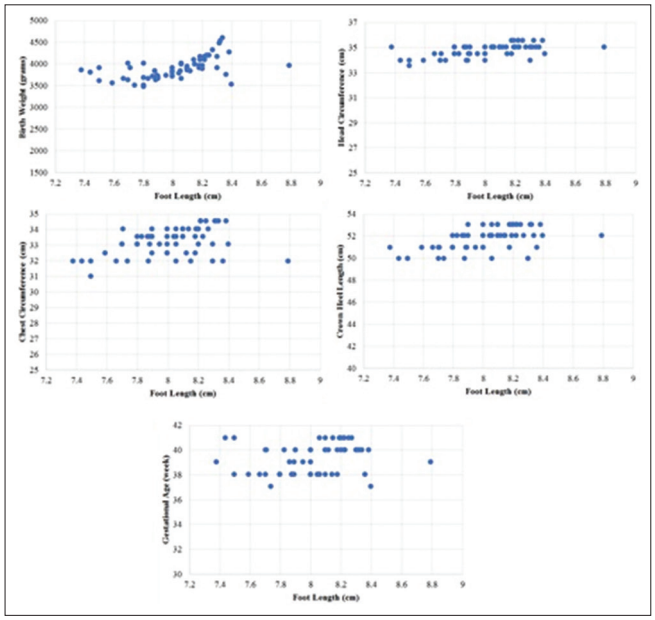

Figure 6: Correlation between foot length and other variables for term large gestational age

as 32.33 ± 0.97 which was comparable to our HC findings [Table 2]. Gupta *et al.*[14] in their study showed that mean CC of preterm SGA and AGA was 26 cm and 28.5 cm, while of term AGA, SGA, and LGA were 31.18 cm, 29.8 cm, and 34.43 cm and of post-term AGA and SGA were 32.55 cm and 31 cm, respectively, similar to our findings [Table 2]. CHL in our study [Table 2] were comparable to the findings in the study done by Gohil *et al.*[15] which showed a mean CHL of 42.7 ± 2.08 cm for preterm babies, 46.21 ± 1.23 cm for term SGA, and 48.36 ± 3.13 cm for term AGA babies, respectively.

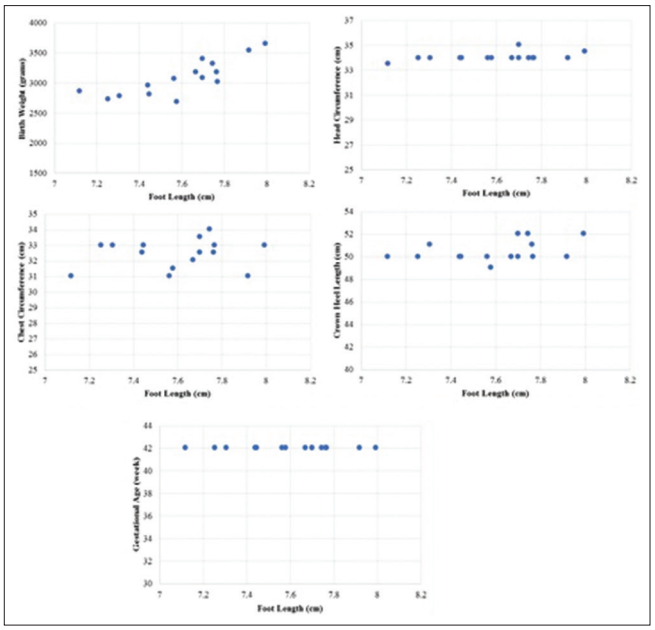

Figure 7: Correlation between foot length and other variables for post-term appropriate gestational age

Table 4: Regression analysis results of relationship between foot length and gestational age assessment by various methods

Gestational age	Foot length		
	R-value	R2-value	*P*-value
LMP	0.815	0.663	<0.001
USG	0.858	0.736	<0.001
Ballard	0.831	0.691	<0.001

LMP: Last menstrual period, USG: Ultra-sonography

FL correlated with GA, BW, HC, CC, and CHL in preterm SGA, pre-term AGA, pre-term LGA, term AGA, and term LGA babies. These results were comparable to studies done by Sateesha *et al.*,[16] Gavhane *et al.*,[12] and Saroj *et al.*[17]

CONCLUSIONS

FL correlated significantly with GA and other anthropometric parameters such as BW, HC, CC, and CHL in most of the GA groups.

FL is a simple, quick, cheap, effective, readily accessible, and a reliable anthropometric measurement which can be used as a proxy measurement to GA assessment/gestational maturity and BW especially in sick and pre-term neonates receiving intensive care.

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