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Foot length of newborn: Its correlation with gestational age and various anthropometric parameters.

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Abstract

Introduction: Neonatal period is the most vulnerable period of life. Neonatal deaths account for 45% of all deaths among Under-five children. The main causes of neonatal deaths are prematurity and low birth weight (LBW). This study was done to assess newborn foot length and determine its utility in identifying LBW/Preterm Babies.

Material and methods: This is a cross sectional study of 500 newborn babies, done in KIMS Hospital and Research Center, Bengaluru. All live newborn infants were included in the study, while babies with lower limb congenital anomalies were excluded from the study.

Results: Among 500 newborns, 55.4% (n=277) were male and 44.6 % (n=223) were females. The Mean ± SD at birth for birth weight(BW), Gestational age(GA) head circumference(HC), chest Circumference (CC), length and Foot Length (FL) were 2.74 ± 0.47 kg, 37.95 ± 2.3 weeks, 33.51 ± 1.73 cm, 31.04 ± 1.73 cm, 47.84 ± 2.58 cm and 7.58 ± 0.44 cm, respectively. Males had slightly higher anthropometric values compared to females which were not statistically significant. We observed a significant correlation between FL and other anthropometric variables namely BW, GA, HC, CC and length with R value of 0.9, 0.87, 0.86, 0.81 and 0.84, respectively and a significant P value of <0.0001. For BW and GA, FL had higher correlation with R value of 0.9 and 0.87, respectively while HC, CC and length had lower values. Using Receiver Operative Characteristic (ROC) curve analysis we found that FL ≤ 7.4cm had 97.03% sensitivity and 87.05% specificity in identifying LBW babies. FL ≤ 7.4 cm had 98.81% sensitivity and 79.09% specificity for identifying preterm babies.

Conclusion: We observed a significant correlation between foot length and other variables namely birth weight, gestational age, head circumference, chest circumference and length. Foot length had a higher sensitivity and specificity in identifying LBW and Preterm babies, making it a reliable variable in rural setup where weighing facilities, ultrasound and trained personnel are not available.

Keywords: Newborn, Low birth weight (LBW), Preterm, Term, Foot length, Gestational age (GA).

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Introduction

Neonatal period is the most vulnerable period of life. Neonatal deaths account for 45% of all deaths among Under-five children. The majority of neonatal deaths (75%) occur during the first week of life and 25% to 45% occur within the first 24 h [1]. The main causes for neonatal deaths are prematurity, low-birth-weight (LBW), infections, asphyxia and birth trauma, accounting for 80% of neonatal deaths [1].

About 60% of the LBW babies are born at term after fetal growth restriction as Small-for-Gestational-Age (SGA) babies, whereas the remaining 40% are born preterm [2]. The burden of SGA births is very high in countries of low and middle income and is concentrated highly in south Asia. Nearly 30% of neonates-7.5 million—are born with LBW (<2500 g) in India, this accounts for about 42% of the global burden. Identifying these LBW and preterm babies and referring them to higher centers for effective interventions will help in decreasing neonatal mortality and morbidity [3].

In developing countries most of deliveries are conducted at peripheral level, where taking accurate weight and assessment of gestational age is difficult because of non-availability of weighing machines, ultrasonography and trained personnel. Simple anthropometric alternatives to measure birth weight have been investigated in various settings to help identify LBW and Preterm babies. Some research studies have investigated newborn foot length (FL) as a screening tool for small babies [4-7]. Foot is easily accessible even in premature babies, babies nursed in incubators, and babies receiving intensive care making it easier to measure FL. FL is quiet simple to measure where the only requirement is a well calibrated ruler or tape and does not require much expertise. A ruler is small, does not take up space, can be taken to deliveries outside a hospital premises i.e. in remote areas, and can be adequately cleaned and sanitized. It is also easy to acquire a well calibrated ruler. FL measurements can thus be used in remote areas to identify high risk newborn babies.

This study was done to find the correlation between newborn FL and other anthropometric variables namely birth weight (BW), gestational age (GA), head circumference (HC), chest circumference (CC) and length and to determine the utility of using newborn FL as screening tool to identify LBW/Preterm Babies.

Materials and Methods

The present study is a cross sectional hospital based study of 500 newborn babies, done in KIMS Hospital and Research Center, Bengaluru. The duration of study was 1 year. All live newborn infants were included in the study. Newborn babies with lower limb congenital anomalies were excluded from the study. GA of each newborn was calculated using the New Ballard Score. Right FL of each baby was measured from the heel to the tip of great toe using a stiff plastic transparent ruler. Length was recorded to the nearest of 0.1 cm on an infantometer with baby in the supine position, knees fully extended and soles of the feet held firmly against the foot board and head touching the fixed board. HC was measured by placing the measuring tape anteriorly at glabella and posteriorly along the most prominent point. CC was measured at the level of nipples by measuring tape to the nearest of 0.1 cm. All the measurements were recorded within 48 h of birth.

Statistical Package for Social Sciences (SPSS) software version 17 and Medcalc 14.8.1 were used to analyze the data. The anthropometric measures of newborn babies are presented as mean and standard deviation (SD) and compared using one-way analysis of variance (ANOVA). Correlation was done to examine linear relationship between two continuous variables. Receiver operating characteristic curve (ROC curve) were used to define the cut-off point which best discriminates between low birth weight and normal birth weight, preterm and term babies, the value which yielded the highest accuracy was determined. Sensitivity, specificity, likelihood ratio for positive test (LR+) and Likelihood ratio for negative test(LR-) were calculated at all cut-points for all anthropometric measurements.

Results

Out of 500 neonates, 55.4% (n=277) were male babies and 44.6% (n=223) female babies. The mean ± SD for BW was 2.74 ± 0.47 kg with minimum and maximum values of 1.02 kg and 3.82 kg, respectively. The mean ± SD for GA was 37.95 ± 2.3 weeks with minimum and maximum value of 27 weeks and 42 weeks, respectively. The mean ± SD for HC of the newborn babies was 33.51 ± 1.73 cm with a minimum and maximum value of 26.1 cm and 37.1 cm, respectively. The mean ± SD for CC was 31.04 ± 1.73 cm with a minimum and maximum value of 23.2 cm and 34.5 cm, respectively. The mean ± SD for length was 47.84 ± 2.58 cm with a minimum and maximum value of 37.3 cm and 52.7 cm, respectively. The mean ± SD for FL at birth was 7.58 ± 0.44 cm with a minimum and maximum value of 5.4 cm and 8.40 cm, respectively (Table 1). Term babies were 83.2% and preterm babies were 16.8%. The percentage of SGA, AGA and LGA babies was 15.2%, 83.6% and 1.2%, respectively.

Table 2 shows the descriptive statistics of anthropometric variables of study population based on sex. Males had a slightly higher anthropometric values compared to females which was not statistically significant.

One-way analysis of variance (ANOVA) test was done to compare anthropometric variables namely HC, CC, L and FL. The mean values for HC, CC, L and FL were significantly higher in term babies compared to preterm babies with a P value of <0.0001 (Table 3). We also observed that mean values for HC, CC, L and FL were

Table 1. *Descriptive statistics of the anthropometric variables of the study population*

Variables	N	Mean	95% CI	SD	Minimum	Maximum	P value
GA (weeks)	500	37.95	37.74-38.15	2.30	27.00	42.00	<0.001
Weight	500	2.75	2.70-2.79	0.47	1.02	3.82	<0.001
HC (cm)	500	33.51	33.36-33.66	1.72	26.10	37.10	<0.001
CC (cm)	500	31.03	30.88-31.19	1.73	23.20	34.50	<0.001
Length (cm)	500	47.84	47.61-48.06	2.58	37.30	52.70	<0.001
Foot Length (cm)	500	7.58	7.54-7.62	0.44	5.30	8.40	<0.001

significantly higher in Large for Gestational Age (LGA) babies compared to Small for Gestational Age (SGA) babies with a P value of <0.0001 (Table 4).

We observed a significant positive correlation between FL and other anthropometric variables namely BW, GA, HC, CC and length with R value of 0.9, 0.87, 0.86, 0.81 and 0.84, respectively and a P value of <0.0001 (Table 5). On comparing BW with other anthropometric variables we found that FL had higher correlation with R value of 0.9 while other variables namely HC, CC, length showed an R value of 0.86, 0.83 and 0.85, respectively. Similarly, on comparing GA with other anthropometric variables we found that FL had higher correlation with R value of 0.87 while other variables namely HC, CC, length which showed an R value of 0.78, 0.74 and 0.75, respectively (Table 6).

Using Receiver Operating Characteristic curve (ROC curve)

1. For identifying LBW babies (Table 7).
   - FL ≤ 7.4 cm had 97.03% sensitivity and 87.05% specificity.
   - HC ≤ 32.9 cm had 86.14% sensitivity and 81.95% specificity.

Table 2. *Descriptive statistics of the anthropometric variables of the study population based on sex*

Variables	Sex	N	Mean	SD	Minimum	Maximum	ANOVA test P value
GA (weeks)	**Female**	277	37.98	2.32	28.00	42.00	0.76
	Male	223	37.90	2.28	27.00	42.00	
Weight (kg)	**Female**	277	2.77	0.48	1.02	3.82	0.80
	Male	223	2.71	0.47	1.03	3.82	
HC (cm)	**Female**	277	33.55	1.72	26.10	37.10	0.75
	Male	223	33.45	1.74	26.20	36.50	
CC (cm)	**Female**	277	31.09	1.75	24.00	34.50	0.50
	Male	223	30.96	1.69	23.20	34.10	
Length (cm)	**Female**	277	47.96	2.53	38.10	52.70	0.52
	Male	223	47.68	2.64	37.30	51.40	
Foot Length (cm)	**Female**	277	7.60	0.46	5.30	8.40	0.40
	Male	223	7.55	0.43	5.60	8.40	

Table 3. *Mean comparison of the selected anthropometric variables of the newborn babies by their maturity status*

Variables	Maturity status	N (%)	Mean (cm)	SD (cm)	ANOVA test P value
HC	**Preterm**	84 (16.8)	31.35	2.04	<0.001
	Term	416 (83.2)	33.95	1.28	
CC	**Preterm**	84 (16.8)	23.20	32.10	<0.001
	Term	416 (83.2)	31.42	1.36	
Length	**Preterm**	84 (16.8)	44.53	2.60	<0.001
	Term	416 (83.2)	48.51	1.99	
Foot Length	**Preterm**	84 (16.8)	6.91	0.49	<0.001
	Term	416 (83.2)	7.71	0.28	

Table 4. *Mean wise comparison of the selected anthropometric variables of the newborn babies by their weight for gestational age*

Variables	Weight for gestational age	N (%)	Mean (cm)	SD (cm)	ANOVA test P value
HC	**LGA**	6	35.53	0.98	P<0.001
	AGA	418	33.83	1.47	
	SGA	76	31.59	1.74	
CC	**LGA**	6	32.95	0.86	P<0.001
	AGA	418	31.36	1.47	
	SGA	76	29.12	1.76	
Length	**LGA**	6	50.43	1.90	P<0.001
	AGA	418	48.38	2.18	
	SGA	76	29.12	1.76	
Foot Length	**LGA**	6	8.05	0.36	P<0.001
	AGA	418	7.63	0.42	
	SGA	76	7.24	0.38	

Table 5. *Correlation between foot length and anthropometric variables*

Variables		Birth Weight	Gestational Age	HC	CC	Length of baby
Foot length	Correlation Coefficient	0.900	0.876	0.865	0.807	0.847
	Significance Level P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	N	500	500	500	500	500

Table 6. *Correlation between birth weight and gestational age with various anthropometric variables*

Variables		HC	CC	Length of baby	Foot length
Birth weight	Correlation Coefficient	0.857	0.831	0.852	0.900
	Significance Level P	<0.0001	<0.0001	<0.0001	<0.0001
	n	500	500	500	500
Gestational Age	Correlation Coefficient	0.782	0.740	0.754	0.876
	Significance Level P	<0.0001	<0.0001	<0.0001	<0.0001
	n	500	500	500	500

Table 7. *Cut-off value of anthropometric indicators for detecting LBW and preterm babies using receiver operating characteristic curve (ROC curve)*

	Variables	Cut-off Value(cm)	Sensitivity	95% CI	Specificity	95% CI
For detecting LBW babies	Foot Length	≤ 7.4	97.03	91.6-99.4	81.95	77.8-85.6
	Head Circumference	≤ 32.9	86.14	77.8-92.2	81.95	77.8-85.6
	Chest Circumference	≤ 30.5	92.08	85.0-96.5	76.44	72.0-80.5
	Length	≤ 46.7	91.09	83.8-95.8	86.72	83.0-89.9
For detecting Preterm babies	Foot Length	≤ 7.4	98.81	93.5-100.0	79.09	74.9-82.9
	Head Circumference	≤ 33	89.29	80.6-95.0	74.52	70.0-78.6
	Chest Circumference	≤ 31.1	89.29	80.6-95.0	64.18	59.4-68.8
	Length	≤ 47.1	86.90	77.8-93.3	78.12	73.8-82.0

- CC ≤ 30.5 cm had 92.08% sensitivity and 76.44% specificity.
- Length ≤ 46.7 cm had 91.09% sensitivity and 86.72% specificity.

2. For identifying preterm babies (Table 7, Table 8).

- FL ≤ 7.4 cm had 98.81% sensitivity and 79.09% specificity.
- HC ≤ 33 cm had 89.29% sensitivity and 74.52% specificity.
- CC ≤ 31.1 cm had 89.29% sensitivity and 64.18% specificity.
- Length ≤ 47.1 cm had 86.9% sensitivity and 78.12% specificity.

Discussion

Early identification of high risk conditions like LBW and preterm babies helps in reducing Neonatal mortality and morbidity in developing countries like India.

This study was 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 identifying LBW and preterm babies.

In this study of 500 newborn babies, 55.4% were male and 44.6% were female. These values are similar to results in studies by Rakkappan et al. [6] (53.7% male, 46.3% female) and Amar et al. [7] (51.4% males and 48.6% females). Term babies were 83.2% and preterm babies were 16.8%, which is comparable to studies by Rakkappan et al. [6] which showed 81.4% term babies and 18.6% preterm babies. The study conducted by Gohil et al. [8] showed term babies at 89.5% and preterm babies at 10.5%.

The percentage of SGA, AGA and LGA babies was 15.2%, 83.6% and 1.2%, respectively. Birth weight of newborn babies in this study ranges from 1.02 to 3.82 kg with the mean of 2.74 kg. Similar findings were seen in studies by Amar et al. [7] (mean birth weight of 2.55 kg) and Rakkappan (mean birth weight of 2.69 kg).

The FL in our study showed a mean ± SD of 7.58 ± 0.44. In a similar study by Marchant et al. [9] Mean FL on the first day was 7.8 cm with standard deviation 0.47 cm. We observed that mean ± SD for FL of term babies (7.71 ± 0.28 cm) was higher than mean ± SD for FL in preterm babies (6.91 ± 0.49 cm).

Attention to FL as surrogate marker came when Streeter, 1920, first observed that the fetal foot could be used to

Table 8. *Cut-off value of anthropometric indicators for detecting using receiver operating characteristic curve (ROC curve)*

Variables	Cut-off Value(cm)	Sensitivity	95% CI	Specificity	95% CI	+LR	-LR
Foot Length	≤ 7.4	98.81	93.5-100.0	79.09	74.9-82.9	4.72	0.015
Head Circumference	≤ 33	89.29	80.6-95.0	74.52	70.0-78.6	3.50	0.14
Chest Circumference	≤ 31.1	89.29	80.6-95.0	64.18	59.4-68.8	2.49	0.17
Length	≤ 47.1	86.90	77.8-93.3	78.12	73.8-82.0	3.97	0.17

estimate gestational age [10]. Studies were done supporting the use of FL as surrogate marker for BW and GA. In this study FL showed positive correlation with BW, GA, HC, CC and length of the baby which is statistically significant. It was observed that FL showed the higher values in correlation, sensitivity and specificity when compared to other variables in identifying LBW and preterm babies. In the study by Marchant et al it was observed that FL<8 cm had sensitivity and specificity of 87% (95% CI 79-94) and 60% (95% CI 55-64) to identify those with low birth weight (<2500 g) and 93% (95% CI 82-99) and 58% (95% CI 53-62) to identify those born premature (<37 weeks). Similar findings were seen in studies by Kc et al. [11] and Daga et al. [12]. Mathur et al. [13] studied Birth weight, crown heel length and FL in 300 newborns and found a linear correlation with gestational age (r=0.98, 0.97 and 0.98, respectively) which were found to be highly significant statistically. Mullany et al. [14] in their study of 1890 newborns found that Chest circumference was superior to FL in classification of infants into birth weight categories.

In this study based on ROC findings we found that FL with 7.4 cm cut off showed higher sensitivity and specificity compared to HC, CC and length in identifying preterm (98.81% sensitivity and 79.09% specificity) and LBW newborns (97.03% sensitivity and 87.05% specificity). In a similar study by Kakrani et al. [15] in 934 newborn found that FL showed significant positive correlation with birth weight. They also found that at cut off point of 6.75 cm, FL had 92.8% sensitivity and 65% specificity in predicting birth weight below 2000 g [15]. In the study by Srivastava et al. [16], FL of 7.37 cm was identified from linear regression analysis as the cutoff point corresponding to a gestational age of 37 weeks. Daga et al. [12] suggested FL with 6.5 cm cut off point, corresponding to 34 weeks gestational age would help identify high risk newborn.

Conclusion

We observed that there was a significant correlation between FL and various other anthropometric variable namely BW, GA, HC, CC and length. FL had a higher sensitivity and specificity in identifying LBW and Preterm babies making it a reliable variable that could be used in a rural setup where weighing facilities were not available. Using foot length we can thus easily identify preterm and LBW babies in remote rural areas and refer them to higher centers.

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