

Utilization of Foot Length as a Non-Invasive Anthropometric Measurement in Neonates Admitted to the NICU in a Tertiary Care Centre in North Karnataka, India

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ABSTRACT

Background: The majority of the neonates in the Neonatal Intensive Care Unit (NICU) would be on respiratory support either invasive or non-invasive ventilation. Therefore, it is difficult to measure anthropometries, such as weight, length, and head circumference in these sick newborns. This study aimed to determine the correlation of foot length with occipitofrontal head circumference (OFC), crown-heel length (CHL), and weight of the newborn.

Methods: A cross-sectional study was conducted at the level IIb NICU of Shri B M Patil Medical College Hospital and Research center, Vijayapur, India. The foot length, OFC, and CHL of the neonates with gestational ages of 28-42 weeks were measured between 12 hours and 7 days of life.

Results: Out of 350 neonates enrolled, 61% and 39% of the newborns were preterm and term, respectively. The correlation between foot length and birth weight ($r=0.90$) and foot length and length ($r=0.89$) was pronounced in premature neonates. Moreover, a positive linear correlation was observed between foot length and weight in neonates of all gestational ages. To identify the low birth weight (LBW) neonates (<2500 gm), a foot length of less than 7.41 cm had sensitivity and specificity of 94% and 50%, respectively. Furthermore, foot length less than 6.62 cm had 100% sensitivity and 67% specificity to identify the very LBW newborns (<1500 gm).

Conclusion: Birth weight and CHL of premature newborns can be estimated from the measurement of foot length that was performed easily and rapidly. Measurement of foot length is valuable in premature neonates who are too ill at birth or those who are on ventilators. Furthermore, foot length may be used in the identification of LBW and VLBW newborns who are admitted to the NICU.

Keywords: Anthropometry, Foot length, Newborn, Preterm, Weight

Introduction

Anthropometric measurements that are alternative to the birth weight of newborns have been assessed in various conditions of neonatal sickness (1, 2). Studies that were conducted in the UK, India, Nepal, and Taiwan have analyzed foot length as a screening tool for newborns, especially premature babies. These studies showed consistent foot length cutoffs to identify very low birth weight (VLBW) (<6.90cms) and

LBW newborns (<7.20cms) (3, 4). The majority of the newborns in the Neonatal Intensive Care Unit (NICU) would be on respiratory support like invasive or non-invasive ventilation; therefore, it is difficult to assess anthropometries, such as weight, length, and head circumference in these preterm babies (5, 6). According to a study conducted by Senthil Kumar K et al., a positive correlation was found between foot length and

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gestational age as determined by the last menstrual period ($r=0.965$) and ultrasound ($r=0.964$) (7). Accordingly, this study aimed to assess the correlation of foot length with occipitofrontal head circumference (OFC), crown-heel length (CHL), and weight of the baby.

Methods

This prospective cross-sectional study was conducted at the level IIB NICU of Shri B M Patil Medical College Hospital and Research Centre, Vijayapur, India, from October 2019 to March 2020.

Sample Size Calculation

The sample size of this study was calculated at 350 newborns admitted to the NICU during the study period. Eventually, with 95% confidence level and $\pm 5.3\%$ margin of error, 346 (~350) subjects were selected in this study to determine the usefulness of foot length as a non-invasive anthropometric measurement in neonates admitted to the NICU using the following formula:

$$n = \frac{z^2 p(1-p)}{d^2}$$

Where, $Z=z$ statistic at a 5% level of significance, d signifies the margin of error, and p presents the anticipated prevalence rate.

Inclusion and Exclusion Criteria

The inclusion criteria were neonates with gestational ages of 28-42 weeks who were admitted to the NICU of Shri B M Patil Medical College Hospital and Research center, Vijayapur, India. On the other hand, the newborns with a congenital anomaly and chromosomal abnormalities were excluded from the study.

The foot length, OFC, and CHL of the neonates with gestational ages of 28-42 weeks admitted to the NICU were measured between 12 hours and 7 days of life. Moreover, the foot length was measured using a digital foot length caliper with a stainless hardened scale while considering aseptic precautions. Furthermore, modified Ballard's scoring system was utilized to calculate the gestational age of each newborn. Similarly, birth weight was measured using a digital Salter scale. The newborns were then classified into 1) preterm <37 weeks, 2) LBW <2.5 kg, 3) VLBW <1.5 kg, and 4) extremely LBW <1 kg.

Statistical Analysis

The data were entered in an excel sheet and analyzed using SPSS software (version 23) through descriptive and inferential statistical analysis. Following that, the results on continuous and categorical measurements were presented as mean \pm SD as well as number and percentage, respectively. Furthermore, ANOVA and repeated ANOVA were employed to assess the significance of the study parameters between three or more groups of newborns. In addition, the correlation among body weight, foot length, and head circumference was analyzed using the Pearson Correlation. It is worth mentioning that the sensitivity and specificity of each foot length were calculated using a non-parametric receiver operating curve. A p-value less than 0.05 was considered statistically significant.

Results

Out of 350 newborns, 61% and 39% of the cases were preterm (<37 weeks) and term, respectively (Table 1). Moreover, 81%, 7.7%, and 11.3% of the neonates were appropriate, large, and small for gestational age, respectively (Table 1). The mean foot length values of the newborns measured on the first day of life were 50.84 \pm 3.80 for ELBW, 58.28 \pm 3.85 for VLBW, and 66.22 \pm 4.37 for LBW (Table 2). The results of the Pearson correlation revealed an association between foot length and weight (-0.9), length (-0.87), and head circumference (-0.89) (Table 3) which showed a significant correlation among the variables (Table 4).

Sensitivity and Specificity of Foot Length

The sensitivity and specificity estimates for foot lengths were measured on the first day of life and plotted in the Receiver Operating Characteristics curves. In the LBW neonates (<2500 gm), a foot length of less than 7.41 cm had 94% and 50% sensitivity and specificity, respectively. However, the VLBW neonates with foot length less than 6.62 cm had 100% and 67% sensitivity and specificity, respectively (<1500 gm) (Table 5).

Table 1. Gestational age classification

Parameters	No. of patients	%
Gestational age		
<37 weeks	216	61.5
≥ 37 weeks	134	38.5
Appropriateness for gestational age		
Appropriate	283	80.8
Large for gestational age	27	7.7
Small for gestational age	40	11.5
Total	350	100.0

Table 2. Mean values of foot length according to weight (kg)

Foot length	Weight (kg)				P-value
	<1	1-1.5	1.5-2.5	>2.5	
Day 1	50.84±3.80	58.28±3.85	66.22±4.37	74.13±4.12	<0.001*
Day 2	50.71±3.91	58.28±3.85	66.23±4.38	74.15±4.08	<0.001*
Day 3	50.71±3.91	59.22±3.18	66.88±4.35	74.17±4.09	<0.001*
Day 4	50.92±4.28	59.36±3.31	66.90±4.36	74.20±4.05	<0.001*
Day 5	51.28±4.09	59.46±3.39	66.92±4.36	74.26±4.00	<0.001*
Day 6	51.47±3.93	59.68±3.30	67.01±4.32	74.41±4.02	<0.001*
Day 7	51.61±3.90	59.68±3.30	66.83±4.14	75.52±2.44	<0.001*
Inter group P-value	0.003*	<0.001*	<0.001*	<0.001*	

*Note: significant at 5% level of significance (P<0.05)

Table 3. Pearson correlation of foot length with weight (kg), length (cm), and head circumference (cm)

Pearson correlation	r-value	P-value
Foot Length day 1 vs Weight day 1	0.891	<0.001*
Foot Length day 2 vs Weight day 2	0.890	<0.001*
Foot Length day 3 vs Weight day 3	0.901	<0.001*
Foot Length day 4 vs Weight day 4	0.905	<0.001*
Foot Length day 5 vs Weight day 5	0.904	<0.001*
Foot Length day 6 vs Weight day 6	0.904	<0.001*
Foot Length day 7 vs Weight day 7	0.906	<0.001*
Foot Length day 1 vs Length day 1	0.871	<0.001*
Foot Length day 2 vs Length day 2	0.873	<0.001*
Foot Length day 3 vs Length day 3	0.875	<0.001*
Foot Length day 4 vs Length day 4	0.876	<0.001*
Foot Length day 5 vs Length day 5	0.875	<0.001*
Foot Length day 6 vs Length day 6	0.874	<0.001*
Foot Length day 7 vs Length day 7	0.876	<0.001*
Foot Length day 1 vs Head circumference day 1	0.898	<0.001*
Foot Length day 2 vs Head circumference day 2	0.899	<0.001*
Foot Length day 3 vs Head circumference day 3	0.898	<0.001*
Foot Length day 4 vs Head circumference day 4	0.896	<0.001*
Foot Length day 5 vs Head circumference day 5	0.897	<0.001*
Foot Length day 6 vs Head circumference day 6	0.896	<0.001*
Foot Length day 7 vs Head circumference day 7	0.896	<0.001*

*Note: significant at 5% level of significance (P<0.05)

Table 4. Pearson correlation of foot length

Pearson correlation	r-value	P-value
Foot Length vs Weight	0.900	<0.001*
Foot Length vs Length	0.870	<0.001*
Foot Length vs Head circumference	0.898	<0.001*

*Note: significant at 5% level of significance (p<0.05)

Table 5. Sensitivity and specificity of foot length

Studies	<1500 gms (VLBW)*			<2500 gms (LBW)**		
	Foot length	Sensitivity	Specificity	Foot length	Sensitivity	Specificity
Ho TY et al. (6)	<7.20cms	80%	80%	<7.90cms	80%	80%
Marchant T (15)	<7.00 cms	75%	99%	<8.00cms	87%	60%
Mukerhjee S (16)	<6.85cms	100%	94%	<7.25cms	80%	100%
Mullany et al. (4)	<6.90cms	88%	86%			
Hirve et al. (3)	<6.30cms	100%	95%			
Sampathkumar P (17)	<6.58cms			<7.45cms		-
Present study	<6.62cms	100%	67%	<7.41cms	93.8%	50%

* Very low birth weight

** Low birth weight

Discussion

This study included 350 newborns and recorded their anthropometric measurements. The majority of the neonates were male (58%). The obtained result is consistent with the finding in a study conducted by Neela. J et al. in which

the majority of the newborns were male (52.4%) (8). In this study, 61% and 39% of the neonates were preterm and term, respectively, whereas in a study performed by Ramji S et al. 89.5% and 10.5% of the neonates were term and preterm,

respectively (9). In this study, 11.5%, 80.8%, and 7.7% of the neonates were small, appropriate, and large for gestational age, respectively, which was in line with the results of a study carried out by Hirve SS (3) et al. (small, appropriate, and large for gestational age were 13.2%, 84.8%, and 2.1%, respectively).

To recognize the high-risk newborns, there is a need for an appropriate and alternate parameter, which can be easily measured with no sophistications (10). Foot length is one of the measurements, which can be measured very easily in critically-ill neonates admitted to the NICU; moreover, it bears good correlation with birth weight and is rapid to perform and a good predictor of gestational age (11). A positive linear correlation was observed in this study between foot length and weight in newborns of all gestational ages. The correlation between foot length and birth weight ($r=0.90$), as well as foot length and length ($r=0.89$), was pronounced in premature neonates.

Furthermore, birth weight and CHL of premature newborns can be estimated using the measurement of foot length that is performed easily and rapidly. Measurements of foot length are valuable in premature neonates who are too ill at birth or those who are on ventilators (12, 13). Drug dosages and intravenous fluid requirements based on body weight or surface area may be indirectly calculated from a measurement of foot length among the sick preterm neonates on respiratory support (14). The foot length cutoffs of <6.62cm and <7.41cm were defined during this study for VLBW and LBW newborns, respectively.

Ho TY et al. (6) reported a foot length cutoff values of <7.20 and <7.90 cm for VLBW and LBW neonates, respectively, along with the sensitivity of 80% and specificity of 80% in their study.

Similarly, Marchant T (15) reported a foot length cutoff values of <7.00 and <8.00 cm for VLBW and LBW neonates, respectively, with a sensitivity of 80% and specificity of 94%. In the studies conducted by Mullany et al. (14) and Mukherjee S (16), foot length cutoff values in the VLBW neonates were <6.90 and <6.85 cm, respectively, which was almost similar to the findings of the present study.

Mukherjee S (16) observed a foot length cutoff value of <7.25 in the LBW babies with sensitivity and specificity of 80% and 100%, respectively, which was in line with the findings of the current study. In the same vein, Hirve et al. (3) observed a foot length cutoff of <6.30 cm in VLBW babies with sensitivity and specificity of 100% and 95%,

respectively, which was consistent with the findings in the present study. According to a study carried out by Sampathkumar P et al., the foot length cutoff values of <6.58 and <7.45cms were found in VLBW and LBW neonates, respectively, which was almost similar to the findings of the present study (17). In resource-limited settings, a low-cost device could be used to categorize premature newborns by measuring foot length and referring to a higher center for preterm care. This study paves the way for utilizing foot length as an anthropometric surrogate measurement to identify preterm and term neonates in need of extra care.

Limitations of the study

Studies with larger sample sizes are necessary to create nomograms predicting baby's routine parameters, such as weight, length, and head circumference just by knowing the foot length.

Implications of the study

Anthropometry measurements, such as weight, length, and head circumference are routinely monitored in newborns. If the newborn is very sick and needs to be resuscitated, immediate ventilation and other intensive treatments have to be initiated, and the neonates should immediately be admitted to the NICU. In such cases, foot length measurement may help in arriving at a reasonable idea of the various anthropometric measurements. This will also help in working out the drug dosages. Foot length measurement can be used as an alternative measurement to the routine anthropometry measurements in neonates admitted to the NICU.

Conclusion

Birth weight and CHL of premature babies can be estimated from a measurement of foot length that is safe, easy, feasible, and cost-effective. Measurements of foot length are valuable in premature babies who are too ill at birth or those who are on a ventilator which could not be weighed. Foot length may be used in the identification of LBW and preterm babies who are admitted to the NICU.

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None is declared.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of the study.

Ethical considerations

The study was approved by the Institutional Ethics Committee of Medical College Hospital and Research Centre, Vijayapur, India.

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