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Original article

Foot Length as an Anthropometric Parameter and Its Correlation with Gestational Maturity in Neonates

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Abstract

Background: About 70% of all perinatal deaths and 50% of all infant deaths in India are attributed to low birth weight (LBW). In this study our aim was to study correlation between foot length, gestational age and other anthropometric measurements to identify LBW or preterm infants without exposing them by unwrapping.

Method: Neonates (within 1-5 days of life) admitted to the Neonatal Intensive Care Units andPostnatal Care wards were screened. New-borns of different gestational age and weight for gestational age, excluding those born with congenital anomalies/ birth defects and with skeletal deformity of foot. Details of history were taken and clinical examination was done. Anthropometric measurements (birth weight, crown heel length, head circumference, foot length) were taken within 5 days of life and by using standardised methods. Gestational age assessment was done using New Ballard's score.

Results: We found a significant correlation of foot length with various parameters of new-borns including gestational age, birth weight, crown heel length, head circumference in this study. Given the value of foot length, birth weight can be predicted by the formula, Birth weight (Kg) = -3.78 + 0.871*foot length. There is also a significant correlation between gestational age and foot length. If the value of foot length is known, gestational age can also be predicted.

Conclusion: In this study we found that foot length is strongly correlated with the gestational age, birthweight and other anthropometric parameters of the new-born. Therefore, foot length can be a reliable substitute for determining the gestational age and birthweight of the new-born.

Keywords: anthropometry, gestational age, neonates, foot length

Introduction

1.1 Background

Infant mortality is one of the common concerns worldwide. Although the infant mortality rate is decreasing with improvement in health facilities, the most challenging part of infant mortality is the large proportion of new-born deaths, mostly in the first week of life. Low birth weight (LBW), deadly congenital abnormalities, and conditions linked to preterm birth are reported to be the main causes of neonatal mortality. [1].

The most precise indices of the population's nutritional status are growth parameters [2]. One of the parameters is birth weight, which is linked to socioeconomic, clinical, racial, genetic, personal, and geographic factors and serves as a key predictor of survival, future growth, and overall development of the child. [3]

In India 70% of perinatal and 50% of infant deaths are attributed to LBW [4]. The prevalence of low-birth-weight babies is 22.5% as reported by National family health survey-3. However, birth weight was reported only in 34.1% of cases of live births, this means that actual numbers might be even higher [5].

1.2 Rationale and knowledge gap

Early identification of LBW is difficult in most communities as the majority of births are conducted by untrained attendants at home. The non-availability of electronic weighing scales makes it difficult to record the weight even if a health worker does reach the household within the first 24 hours. Various anthropometric measurements have been identified as proxy measures for birth weight during the first week of life [6]. Gestational age and birth weight are critical indicator for the risk of neonatal mortality. For any given gestational age, lower the birth weight,

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higher are the chances of neonatal mortality. [7]
Alternative anthropometric measurements (mid-upper arm circumference and chest circumference) have been used to detect LBW or premature infants in the past. Since it does not involve much training or the newborn being unwrapped, which could expose the infant to hypothermia, foot length has been identified in recent studies as a particularly useful screening method to identify LBW and/or preterm infants in the community [8].

1.3 Objective:

This study aimed to find additional anthropometric parameters that does not involve much trainingor the newborn being unwrapped, which could expose the infant to hypothermia. The objective includes studying the correlation between foot length, gestational age and other anthropometric measurements (birth weight, crown heel length and head circumference to identify LBW or preterm infants in a tertiary care centre of Western Maharashtra, India.

Methods:

This cross-sectional study was conducted at a tertiary care centre in Western Maharashtra, India. Neonates delivered by Caesarean section/normal vaginal delivery and who were within 1 to 5 days of life and were admitted to the Neonatal Intensive Care Unit (NICU) and Postnatal Care (PNC) wards of the hospital were screened for their eligibility. We included new-borns of different gestational age (preterm, term and post-term) and weight for gestational age (SGA/ AGA/ LGA), excluding those born with congenital anomalies/ birth defects and with skeletal deformity of foot. Study procedures were explained to their parents and those who agreed for participation of their babies have signed an informed written consent.

Approval from the Institutional Ethical committee was obtained before starting the study, and consent from parents was taken before enrolling in study. General and clinical information was recorded in a pretested proforma.

Anthropometric measurements were performed within 5 days of life and by using standardised methods. They included, body weight (kg/gms) was measured using electronic weighing scale (SECO baby weighing scale), crown heel length (cm) was measured by an Infantometer (MCP baby infantometer)), a flexible, non stretchable measuring tape was used for measuring head circumference (cm). Foot length (cm) was measured by an electronic sliding calliper (Themisto TH-160 Digital Vernier Calliper) with accuracy of a millimetre. It was measured from heel to great toe of right foot.At the time of measuring, the ventral surface of the foot was straightened out by applying gentle pressure. Gestational age assessment was done using New Ballard's score.

Statistical Analysis:

The data was analyzed using SPSS (Version 16.0) software. Correlation and regression analysis was done to establish correlation. Correlation coefficient (r) values and p-values are indicated wherever required.

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Results

A total of 800 neonates 408 males and 392 females were enrolled. Of these, 178(22%) were admittedin the NICU and 622(78%) were from PNC wards. An average birth weight in neonates studied was 2.6±1.29 kgs (Table 1).

Ward	No of newborn	Percentage
NICU	178	22%
PNC	622	78%
Total	800	100

Table 1: Distribution of newborn in NICU and PNC

Neonates under study were distributed according to maturity and weight for GA. Among 139(17.3%) preterm neonates, 109(13.6%) were AGA and 30(3.7%) were SGA. Among 592(74%) term neonates 489(61.1%) were AGA, 27(3.3%) were LGA and 76 (9.5%) were SGA. Among 69(8.6%) post term neonates, 50(6.2%) were AGA, 2 were (0.2%)LGA and 17(2.1%) were SGA (Table 2)

Maturity	AGA	LGA	SGA	Total
Preterm	109(13.6%)	0	30(3.7%)	139(17.3%)
Term	489(61.1%)	27(3.3%)	76(9.5%)	592(74%)
Post Term	50(6.2%)	2(0.2%)	17(2.1%)	69(8.6%)
Total	648(81%)	29(3.6%)	123(15.3%)	800

Table 2: Distribution of neonates according to maturity and weight for GA

We performed the correlation studies (Pearson correlation) between foot length and GA, birth weight, head circumference, crown heel length in group with different combination of GA and birthweight.

In preterm AGA, Significant correlation was seen among the foot length of new bornand gestational age, birth weight, head circumference, crown heel length (r-value and p-Value is indicated in Table 3).

Correlation between foot length and	n	r Value	P Value
Gestational age	136	0.74	<0.0001
Birth weight	136	0.496	<0.0001
Head circumference	136	0.669	<0.0001
Crown heel length	136	0.621	<0.0001

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b Table 3: Correlation parameters (preterm AGA group)

We further looked at correlation in preterm SGA group. There was no significant correlation among the foot length and gestational age, birth weight, head circumference, crown heel length (r-value and p-Value is indicated in Table 4).

Correlation between foot length and	**n**	**r Value**	**P Value**
Gestational age	3	-0.96	>0.05
Birth weight	3	0.58	>0.05
Head circumference	3	-0.04	>0.05
Crown heel length	3	-0.98	>0.05

Table 4: Correlation parameters (preterm SGA group)

In term AGA, Significant correlation was seen among the foot length of new born and gestational age, birth weight, head circumference, crown heel length (r-value and p-Value is indicated in Table 5).

Correlation between foot length and	**N**	**r Value**	**P Value**
Gestational age	489	0.43	<0.0001
Birth weight	489	0.13	<0.005
Head circumference	489	0.23	<0.0001
Crown heel length	489	0.29	<0.0001

Table 5: Correlation parameters (term AGA group)

In term SGA, Significant correlation was seen among the foot length of new born and gestational age, birth weight, crown heel length and no significant correlation between foot length and head circumference was found (r-value and p-Value is indicated in Table 6).

Correlation between foot length and	**N**	**r Value**	**P Value**
Gestational age	76	0.47	<0.0001
Birth weight	76	0.66	<0.0001
Head circumference	76	0.14	>0.05
Crown heel length	76	0.59	<0.0001

Table 6: Correlation parameters (term SGA group)

There was also the foot length of new born and head circumference, crown heel length, however, no significant correlation between foot length and gestational age and birth weight was seen (r-value and p-Value is indicated in

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Table 7).

Correlation between footlength and	N	r Value	P Value
Gestational age	27	0.34	>0.05
Birth weight	27	0.36	>0.05
Head circumference	27	0.49	<0.01
Crown heel length	27	0.41	<0.05

Table 7: Correlation parameters (term LGA group)

In post term AGA group, significant correlation was seen among the foot length of new born and birth weight i.e. when birth weight increases foot length also significantly increases and no significant correlation between foot length and gestational age, head circumference, crown heel length (r-value and p-Value is indicated in Table 8).

Correlation between foot length and	N	r Value	P Value
Gestational age	50	-0.07	>0.05
Birth weight	50	0.47	<0.001
Head circumference	50	0.15	>0.05
Crown heel length	50	0.05	>0.05

Table 8: Correlation parameters (post term AGA group)

In post term SGA group there was no significant correlation among the foot length and gestational age, birth weight, crown heel length (r-value and p-Value is indicated in Table 9)

Correlation between foot length And	N	r Value	P Value
Gestational age	17	0.12	>0.05
Birth weight	17	0.42	>0.05
Head circumference	17	-0.01	>0.05
Crown heel length	17	0.14	>0.05

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Table 9: Correlation parameters (post term SGA group)

Further we wanted to understand if there was any correlation between gestational age and foot length in our study population. We found a significant positive correlation between foot length and overall gestational age, preterm and term gestational age, however there was no correlation with post term gestational age (Figure 1).

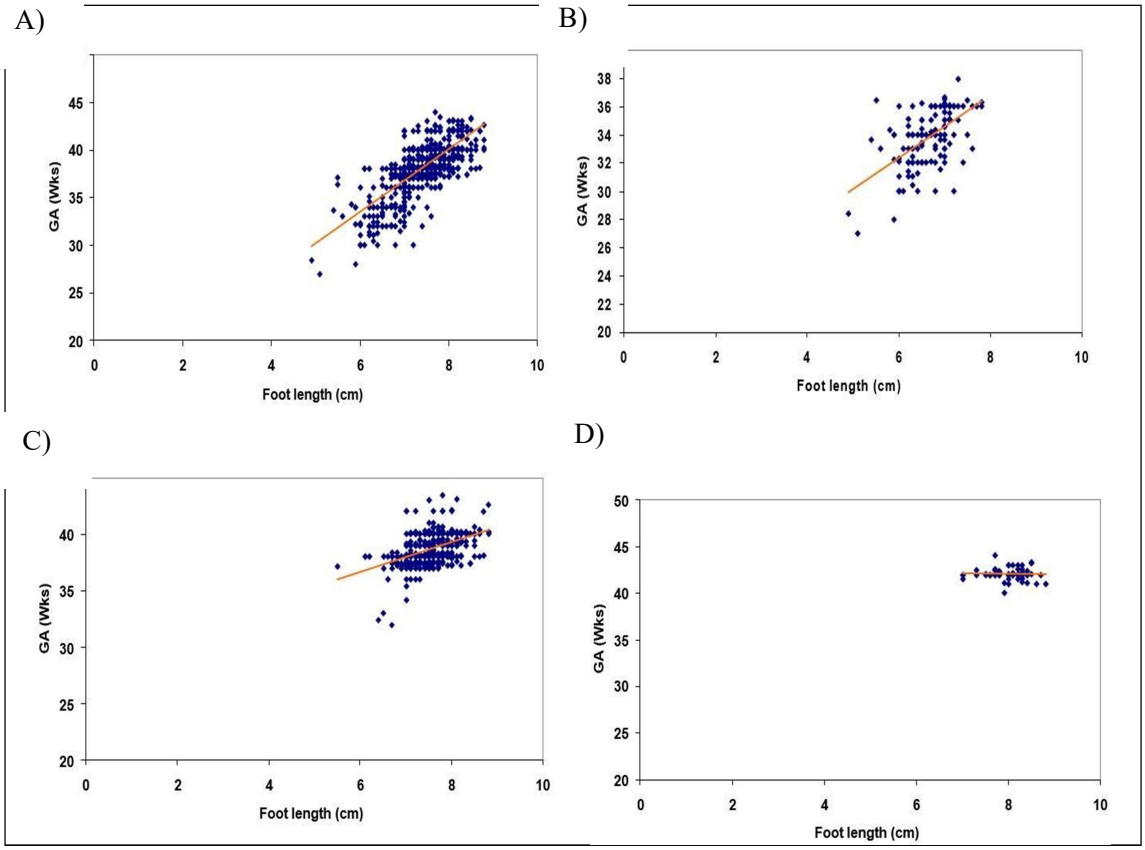

Figure 1: Scatter diagram showing correlation between foot length and Gestational age in study group.A.) Overall GA. r =0.073, p <0.0001 B) Preterm. r =0.57, p <0.0001 C) Term. r =0.43, p <0.0001
D) Post term. r =-0.03, p >0.05.

We were also interested in looking at the correlation between foot length and other birth parameters. Interestingly, we found a strong positive correlation between foot length and birth weight, Crown heel length, Head circumference.

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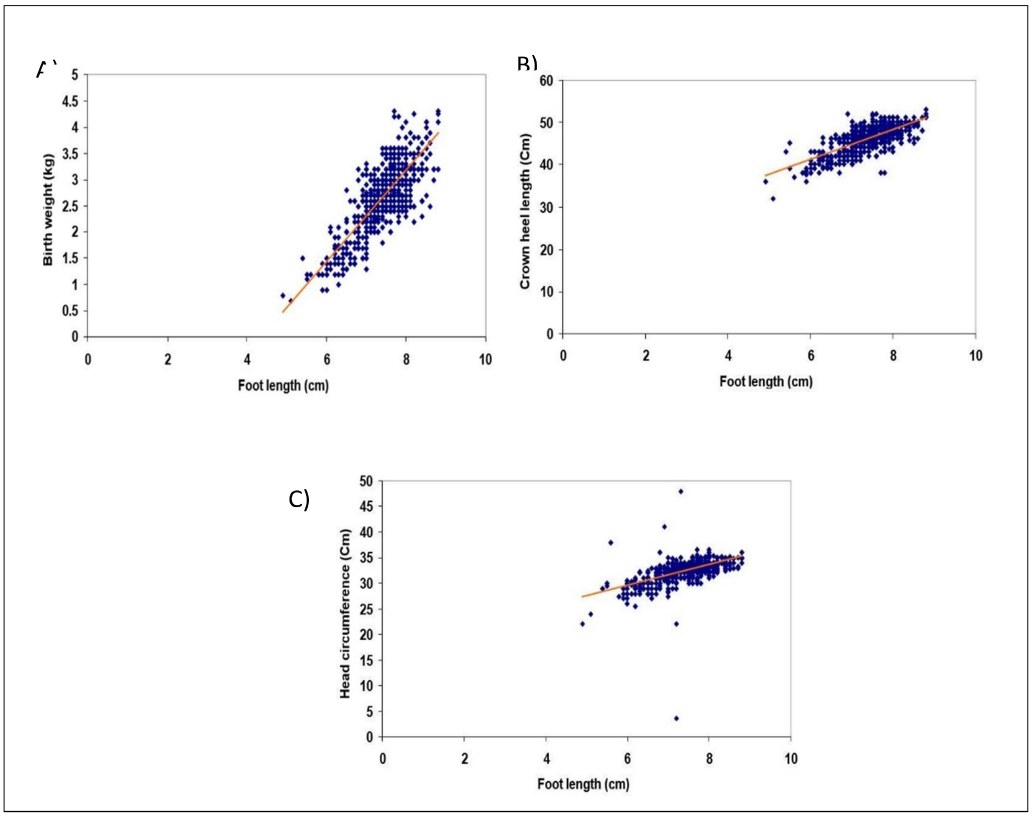

Figure 2: Scatter diagram showing correlation between foot length and birth weight, Crown heel length, Head circumference in study group. A.) Birth weight. r =0.39, p <0.0001 B) Crown heel length.r =0.625, p <0.0001 C) Head circumference. r =0.56, p <0.0001

Discussion

Our study shows the correlation between foot length, GA and various other anthropometric parameters in 800 neonates admitted to the tertiary care Centre. Foot length can be used as a reliable substitute for estimation of birth weight and gestational age, as the assessment of gestational age by Ballard score is time consuming and requires handling of sick neonates. In current research, out of the 800 neonates (51% males and 49%females), 22% were admitted to NICU and 77.7% were from PNC. Similar sex ratios were reported. Among 17.3% preterm neonates, 13.6% were AGA and 3.7% were SGA. Among 74% term neonates, 61.1% were AGA, 3.3% were LGA and 9.5% were SGA. Among 8.6% post term neonates, 6.2% were AGA, 0.2% were LGA and 2.1% were SGA.

In this study, in preterm AGA neonates, a positive correlation was found between foot length and gestational age, birth weight, head circumference and crown heel length. As gestational age, birth weight, head circumference and crown heel length increases foot length also significantly increases. This was in concurrence with a study by Gavhane et al., 2015 where they show a positive correlation between foot length of preterm AGA and crown heel length (0.654, P<0.0001), birth weight (0.714, P<0.001), head circumference (0.713, P<0.001) (9).

Similarly, we also found a positive correlation between foot length and gestational age, birth weight, head circumference and crown heel length in term AGA. As gestational age, birth weight, head circumference and crown heel length increases foot length also significantly increases. These results were comparable to the study done by Gavhane et al., 2015, Ho et al., 2009 and Dagnew et al., 2020 (9,

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10, 11).

In the term SGA neonates of the study, there was positive correlation between foot length and gestational age, birth weight, and crown heel length but not with the head circumference. However, studies done by Gavhane et al., 2015 showed no correlation between foot length and crown heel length [9].

In LGA term neonates, we observed significant correlation between foot length and head circumference, crown heel length and no correlation were observed between foot length and gestational age, birth weight. In contrast, study done by Gavhane et al., 2015 showed no correlation between foot length and crown heel length in this group [9].

In post term AGA neonates, we showed a positive significant correlation between foot length and birth weight, while no significant correlation was seen between foot length and gestational age, head circumference, crown heel length. These results were however in contrast with the study by Mathur et al., 1984 where they showed that the foot length had a statistically significant correlation with crown to heel length [12].

Based on the regression analysis the regression equation for birth weight on foot length according to our study was, Birth weight (Kg) = -3.78 + 0.871*foot length. Therefore, If the value of foot length is known, then birth weight can be predicted. A study conducted by Ho et al., 2009, assessed the growth from foot length in Taiwanese neonates. The regression equation for birth weight (Y) on foot length (X) was obtained as Y = 486.2 + 360.4 X ($P<0.0001$, $r=0.421$). [11]

The regression equation for gestational age on foot length was, Gestational age (Weeks) = 13.75 + 3.28*foot length. Thus, If the value of foot length is known then gestational age can be predicted. Study done by Singhal et al., 2014 showed that, foot length correlated very well with the gestational age with $r = 0.93$ and regression equation obtained was: $Y = 6.278 + 4.15X$ to predict gestational age (Y) from foot length (X) [13].

Our study aimed at adding knowledge to the domain of infant assessment and management, however, it has certain limitations. It was a hospital based study with small sample size without any follow up hence may not be representative at population level. Also, Foot length was not estimated in neonates with foot deformity. Follow up studies could further strengthen the use of foot length in the assessment of birth weight and gestational age.

Conclusion:

Significant correlation was seen between foot length and gestational age (preterm AGA, preterm SGA, term AGA and term SGA). Foot length was also correlated with other growth parameters like birth weight, head circumference and crown heel length significantly. The correlation (r value) of foot length with gestational age and other parameters was higher in preterm neonates (0.57) than in term neonates (0.43)

We conclude that Foot length can be used as an alternative for estimation of maturity of the new-born along with birth weight. Foot length is a simple, quick and reliable anthropometric measurement which can be used as a proxy measurement for screening of low birth weight and prematurity. It can be easily measured by inexperienced health care staff and traditional birth attendants in the community. Study needs to be done with a larger sample size so that standard nomograms can be established and community health workers can assess the premature and low birth weight neonates and refer them to higher centers.

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