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Foot length measurement: As a simple screening method to identify preterm newborns in community

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Abstract
Objectives: To find correlation between foot length and gestational age (GA) and to derive cut off value of foot length to identify preterm neonates.
Design: Present study is observational, cross sectional study.
Setting: Hospital based study, conducted in Swami Dayanand hospital, Delhi over a period of eight months (September 2017-May 2018).
Participants: Total of 400 neonates aged 0 to 48 hours of life delivered in hospital. Inclusion criteria: All live neonates born in SDN hospital during study period, whose GA estimate was available by last menstrual period (LMP). Exclusion criteria: (1) Neonates with congenital anomalies, (2) Newborn whose mother's LMP was not reliable, (3) Difference between GA by LMP and New Ballard score was more than 2 weeks. GA was estimated by LMP and New Ballard score. LMP was considered as gold standard. Selection procedure: Convenience sample.
Outcome measures: Correlation between foot length and gestational age.
Results: A statistically significant positive correlation (r=0.759, *p*< 0.0001) was observed between GA and foot length of newborns. Foot length cut off value for preterm babies of <37 week was observed to be ≤ 7.3 cm with a sensitivity and specificity of 83.53% and 87.94% respectively. For babies <34 week, foot length cut off was ≤7.1 cm, with a sensitivity and specificity of 95.83%, and 88.30% respectively. A simple regression equation for estimation of GA was derived using foot length; GA=13.10+3.33*FL.
Conclusion: Foot length can be used as a simpler method to identify preterm in resource limited areas for their timely referral and management.

Keywords: Preterm, foot length, gestational age

Introduction
Prematurity and low birth weight is the leading causes of neonatal mortality globally. Complications related to prematurity were responsible for nearly 1 million deaths in 2015 among children under five years of age worldwide. In India, there are 3.5 million preterm births every year [1]. Mortality and morbidity related to prematurity can be prevented by early identification and proper care of preterm infants. To assess gestational age of neonates various methods are used, commonly used ones are antenatal ultrasonography, last menstrual period (LMP), New Ballard score (NBS) [2] and anthropometry. New Ballard score is most widely used method to assess gestational age but it is difficult to perform as it needs expertise and much skill, and it is difficult to perform in sick and ventilated babies. We need a method which is simpler and can be used by health workers in peripheral areas to identify and early referral of preterm newborns. Foot length measurement has been used to assess gestational age of neonates in many previous studies. In this study foot length is used as an anthropometric marker to predict gestational age of newborns. FL is easy to measure and no specific tools are required for its measurements. The study aims to find correlation between newborn foot length and gestational age, and to derive cut off value for foot length to identify preterm babies. As newborns less than 34 weeks are more prone to develop complications and are candidate for admission in most of the SNCU in India, this study also aims to find cut off value of foot length for these neonates separately.

Material and Methods
The present study is hospital based analytical, cross sectional study. This study was conducted in NICU and PNC wards of Swami Dayanand hospital, Delhi after obtaining the approval of institutional Research Committee and Institutional Ethical Committee.

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We assessed total 400 singleton newborns within 48 hours of birth over a study period of 8 months (September 2017-May 2018). New Ballard Score was done for all the inborn babies delivered in study period. A brief interview was conducted with mother to enquire about her menstrual details. Gestational age was calculated using Naegele's formula [3] and it was matched with gestational age calculated by NBS. Gestational age calculated from LMP was regarded as gold standard for this study. Neonates for whom reliable information about gestational age using LMP was not available and those with gross congenital anomalies were excluded. Newborn in whom difference of gestational age by LMP and by NBS was more than two weeks, were also excluded. All eligible subjects were included in the study after obtaining proper consent from mother / father / guardian. Weight and foot length was recorded by standard methods. The baby was weighed using a digital electronic scale. The foot length was measured as a distance from the heel to the tip of longest toe of right foot, parallel to the long axis of foot. The right foot was kept straight and foot length was measured using transparent plastic ruler with graduations in millimeters. A difference of not more than +/- 1 mm was present in foot length measured by two different observers in initial 20 neonates.

Sample size

With reference to previous studies [4, 5, 6], a sample size 0f 385, one can be 95% confident that the mean gestational age of newborns will be within 5 days of the actual mean of the total newborn's population. The formula for determining sample size is;

$$n = \left(\frac{Z\sigma}{E}\right)^2$$

= (1.96*5) / 0.5*0.5
= 385

The statistical analysis was performed using SPSS software version 17.0. Anthropometric variables were expressed as mean ± standard deviation. To determine correlation of gestational age with foot length, linear regression analysis was used. Receiver operating characteristic (ROC) was plotted for deriving a cut-off value of foot length for predicting preterm babies. For all statistical tests, a P-value

< 0.05 is considered to be statistically significant.

Results

Out of total 400 newborns enrolled in the study, 58.5% (n=234) were male, and 41.5% (n= 166) were female babies. Among four hundred newborns 78.25% (n=313) were term, 21.25% (n=85) were preterm and only 0.50% (n=2) newborns were post term. Total no. of preterm of GA <34 week was 6% (n=24). The percentage of AGA (n=32), SGA (n=59) and LGA (n=17) babies were 81%, 59% and 4.25% respectively**.** Gestational age (by LMP) ranged from 22.1 weeks to 42.1 weeks with mean gestational age 38.19 ± 2.4. Mean birth weight was 2.68 ± 0.62 kg with minimum and maximum values of 0.5 kg to 5.2 kg respectively. Among total neonates, 32.25% were of low birth weight, and rest 67.75% were of normal birth weight. Mean foot length was found to be 7.56 ± 0.57 cm, ranging from 3.90 cm to 9.20 cm. Table 1 shows baseline characteristics of study population.

Table 1: Baseline characteristics of study population

Parameter		Number (N=400)	Percentage (%)
Sex	Male	234	58.5
	Female	166	41.5
Gestational age	Term	313	78.25
	Preterm	85	21.25
	Preterm (<34 weeks)	24	6.00
	Post term	02	0.50
Weight for gestational age	AGA	324	81
	SGA	59	14.75
	LGA	17	4.25
Parameter	Mean		SD
Gestational age (weeks)	38.19		2.4
Birth weight (kg)	2.68		0.62
Foot length (cm)	7.56		0.57

To find correlation between foot length and gestational age linear regression analysis was done. Figure 1 shows correlation of foot length with gestational age.
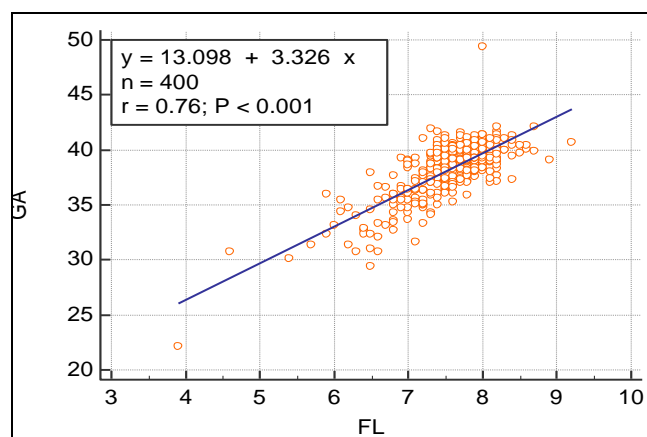
**Fig 1:** Scatter diagram with regression line for Gestational age and Foot length

In this study we observed a statistically significant strongly positive correlation between FL and GA with r=0.759, p<0.0001. We also derived regression equation as shown in figure 1.

GA=13.10+ (3.33* FL)
R^2=0.576, p<0.0001

Data was analyzed separately for preterm babies which also shows strong positive correlation of foot length with GA with r=0.754, p<0.0001.

Cut off values of foot length for preterm babies were obtained from Receiver operating characteristic curve (ROC) as shown in figure 2 and optimal cut off was chosen by Youden index, (Y-Index). Table 2 shows cut off values of foot length for preterm babies.
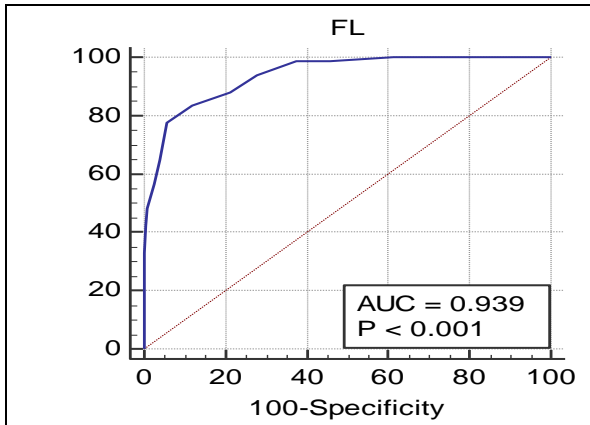
Fig 2: Receiver operating characteristic curve of foot length for predicting preterm neonates

Table 2: Optimal cut off values of FL in preterm babies at various gestational age

Gestational age	Foot length	Sensitivity	Specificity
<37 weeks	≤7.3 cm	88.24%	87.94%
<34 weeks	≤7.1 cm	95.83%	88.30%

- For < 37 weeks- FL ≤7.3 cm had 83.53% sensitivity and 87.94% specificity.
- For <34 weeks- FL≤7.1 cm had 95.83%, sensitivity and 88.30% specificity.

Discussion

Present study was conducted to find correlation between foot length and gestational age and to find cut off value of foot length to detect preterm neonates.

In our study total 400 neonates were included and examined within 48 hours of birth.

In present study mean foot length was found to be 7.58 ± 0.57 cm which is comparable to study by Srinivasa et al. [6] in which mean foot length was 7.58 ± 0.44 cm.

In present study foot length was correlated with gestational age to achieve primary objectives of study. The study shows that there is a significantly positive correlation between gestational age and foot length (r=0.759). Table 3 shows that most of the studies have concluded that foot length have a good linear correlation with gestational age.

Table 3: Comparison of correlation of FL and GA in various studies

Study	Sample size	Correlation coefficient (r)
Present study	400	0.759
Thawani et al. [7] (2013)	1000	0.430
Shrivasatava et al. [4] (2015)	254	0.990
Rakkappan et al. [5] (2016)	1000	0.807
Kumar et al. [11] (2017)	209	0.886
Shrinivasa et al. [6] (2017)	500	0.870
Farah et al [8] (2018)	152	0.533

Result of our study is closest to study of Rakkappan et al. [5]. In present study there were 78.25% term and 21.25% were preterm babies, which is akin to study of Rakkapan et al [5] which included 81% term babies and 18.6% preterm babies. A weak correlation between FL and GA was observed by Thawani et al. [7], while strongest positive correlation was observed by shrivastava et al. [4].

In present study Foot length cut off value for preterm babies is observed to be ≤ 7.3 cm with a sensitivity and specificity of 83.53% and 87.94% respectively. Foot length cut off observed in our study is close to cut off suggested by Shrivastava et al. [4] and Srinivasa et al. [6] as mentioned in table 4.

Table 4: Foot length cut off in various studies

Study	GA<37 weeks	GA<34 week
Present study	≤7.3 cm	≤7.1 cm
Daga et al. [9] (1988)	-	≤6.4 cm
Shrivastava et al. [4] (2015)	≤7.37 cm	-
Kumar et al. [11] (2017)	-	≤ 7 cm
Srinivasa et al. [6] (2017)	≤ 7.4 cm	-
Farah et al. [8] (2018)	≤7.050 cm	-

Shrivastava et al. [4] in 2015, with a sample size of 254 observed a foot length cut off at 7.37 cm to identify preterm babies. In 2017, Srinivasa et al. [6] observed a cutoff point at ≤ 7.4 cm (sensitivity-98.81%, specificity-79.09%) to identify preterm.

Recently Farah et al. [8] in 2018 observed foot length cut off of ≤ 7.050 cm (sensitivity-75%, specificity-98.1%) to identify preterm. In their study sensitivity is low which may result in failure to detect all the preterm babies.

We observed foot length cut off for preterm babies at gestational age <34 weeks also. As babies <34 week are more likely to develop more complications as suggested by Daga et al. [9], they need urgent referral. At <34 weeks we observed a foot length cut off of we observed a foot length cut off value of ≤7.1 cm, with a sensitivity and specificity of 95.83%, and 88.30% respectively.

Similar study was done by Daga et al. [10] in 1993 with a sample size of 200. They observed a cutoff point at ≤ 6.5 cm to identify <34 weeks babies. They recommended immediate referral of these babies and supervision for those babies having foot length of 6.5-7.0 cm.

In 2017, Kumar et al. [11] found the cutoff point of ≤ 7 cm (sensitivity-98.4%, specificity-61.4%) to identify preterm of <34 weeks, which is close to the cut off as suggested by present study. In our study for a cut off of 7.1 cm sensitivity is 95.83% which is comparable to study of Kumar et al. [11] but specificity is higher in present study which makes the

cut off value of ≤7.1 cm, both sensitive and specific in identifying preterms of <34 weeks.

Limitations of study: Present study is hospital based study with a small sample size and less number of premature babies, due to limitation of study period we could not validate results of our study on normal population.

Conclusions
The study concludes that there was a significant positive correlation (r= 0.759) between foot length and gestational age which signifies that it is a good predictor of gestational age in neonates. For calculation of gestational age regression equation is: GA=13.10+3.33*FL. For the observed cut off value, foot length has a good sensitivity and specificity to identify preterm babies so can be used as a screening tool to identify these babies in remote and resource limited peripheral areas.

Key message
What is already known?
There is a positive correlation between foot length and gestational age.

What this study adds?
- This study gives cut off values of foot length to identify pretern neonates. (GA < 37 weeks- FL ≤ 7.3 cm, and GA < 34 weeks- FL≤ 7.1 cm.).
- Regression equation for estimation of gestational age; GA=13.10 +3.33* FL

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