# Correlation of Foot Length of Newborn with Gestational Age

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## Abstract

**Objective:** To measure the foot length of Newborns and to compare foot length to gestational age assessed by Ultrasound.

**Study design:** It was a prospective Observational Foot length of Newborns fulfilling inclusion criteria was measured using electronic sliding caliper with an accuracy of one tenth of a millimetre. Head circumference was measured using flexible, non-stretchable measuring tape using cross tape method by Placing the measuring tape just above the eyebrows and ears, widest part of the head will be measured. Crown heel length will be measured using infantometer. All infection prevention, precaution standards were used during the time of measurement. Standard precautions were also applied for measuring equipment. All the measurements were taken within 24 hours of birth. After collection of data appropriate statistical test was applied.

**Results:** The AUC score based on ROC curve was 0.90. The optimal cut-off foot length for full term categorization was 75.2 mm. The identification of preterm newborns with foot length < 75.2mm had a sensitivity of 92.0%, which means that 92% of preterm newborns (<37 weeks) can be detected by a foot length examination, specificity of 90.0% means that there is a 90% improbability of full term gestational age (more than 37 weeks) in newborns who have a foot length <75.2mm.

**Conclusion:** In conclusion, newborn foot length can be used to predict gestational age. Longer newborn foot length is indicative of higher gestational age. The optimal cut-off point for diagnosing full term babies was 7.52 cm. Foot length <7.52 cm can be used to diagnose preterm babies. Newborn foot length is a reliable anthropometric measurement to diagnose preterm babies.

**Key words:** Foot Length; Gestational Age;

## Introduction

Newborns may have various complications depending on their gestational age . As term , preterm and post term Newborns have different group of problems, Identification of gestational age, especially within 48 hours of birth, is crucial for newborns, as the earlier preterm status is detected, the earlier the child can receive optimal management. Gestational age is a major determinant of newborn prognosis.

Newborns are categorized as preterm, full term, or post-term neonates depending upon gestational age. A normal pregnancy can range from 37 (0/7) to 41(6/7) weeks. Infants born before 37 completed weeks are considered premature &amp; those after 42 weeks are considered post mature [1]

Appropriate for Gestational age Newborns have lower rates of problems and death than newborns that are small or large for their gestational age. Small for gestational age (SGA) is a neonate whose birth weight is less than 10 th percentile for gestational age &amp; Large for gestational age (LGA) newborns have birth weight <90 th percentile [1].

Gestational age (GA) can be estimated by Naegele's formula or ultrasonography. GA estimates based on Naegele's formula in settings with low literacy tend to have lower accuracy [2]. New Ballard Score (NBS) is a valid and reliable clinical tool for GA assessment. However, its accuracy depends on the special training and skill of the examiner and the neonate's condition [3]. In order to reduce global neonatal mortality, early identification of gestational age is necessary to differentiate between preterm &amp; post term from full-term newborns born at home or in remote areas.

Globally, 13 million Newborns are born preterm annually with the prevalence rate ranging from 47.5 to 137 per 1000 live births [4, 5]. In India, among the total 27 million Newborns born annually, 3.6 million Newborns are born preterm, and over 300,000 of these preterm Newborns die each year because of associated complications. Mortality and morbidity can be prevented if at risk newborns are identified early and managed associated complications with simple interventions such as skin-to-skin contact or kangaroo mother care (KMC), early breastfeeding, as well as early infection prevention and treatment. However, identification of preterm &amp; post term newborns is difficult in community settings. As a result, an inexpensive and simple method is required to identify at-risk newborns soon after birth for referral to higher center . Foot length (FL) has been determined in neonates using simple measuring instruments and can be used as an anthropometric surrogate for estimation of GA. Neonatal anthropometric measurements are of both epidemiological and clinical use. In the World Health Organization's 2012 'Born too soon', it was stated that 'simplified approaches to identify preterm Newborns such as foot size' were required for the early identification and management of preterm Newborns.[6] Newborn foot length is an anthropometric measurement which is easy to perform, inexpensive, and potentially efficient for predicting gestatational age. Clinically, the anthropometric measurements are valuable tools used to detect neonates that are at higher risk of neonatal and postnatal morbidity and need for growth improvement [7,8]

**Methods:**

After receiving clearance from institutional review board and ethics committee, a properly designed proforma was used to collect relevant information. Medical records were reviewed for first trimister ultrasound findings, estimated date of delivery and gestational age. Following confirmation of the normal appearance of foot by physical examination, the study subjects were recruited to the study, all neonates born in hospital were enrolled in the study. SGA,LGA,Twins, Parents not giving consent for study,Major congenital anomalies,Mothers with no Ultrasound records were excluded. Gestational assessment was done by available USG records of first trimester. Based on gestational age, Newborns were grouped as preterm, term and post term Newborns. Anthropometric measurements was done on all Newborns within 24 hours of life.

Birth Weight of the baby measured using electronic weighing scale. The scale has an accuracy of ±5 grams. Weight is charted on Fentons growth curve and newborns were categorized as small for gestational age (SGA), appropriate for gestational age (AGA), Large for gestational age (LGA). SGA &amp; LGA newborns were excluded from study.

Foot length of Newborns fulfilling inclusion criteria was measured using electronic sliding caliper with an accuracy of one tenth of a millimetre .Foot length was measured from posterior most prominence of foot to the tip of the longest toe of the foot so as not to elicit a grasp reflex, which may shorten the measurement. The baby  left foot is held in the examiner;s left hand and the calipers is held in his right.

The heel is placed against the platform and the head of the first metatarsal and medial aspect of the heel are aligned parallel with the edge of the instrument. The index finger of the examiners right hand manoeuvres the sliding bar until it just touches the tip of the longest toe. The instrument is withdrawn and the scale was read. similar procedure was done with the right foot and average length was taken as the length of the foot . Head circumference was measured using flexible, non-stretchable measuring tape using cross tape method by Placing the measuring tape just above the eyebrows and ears, widest part of the head will be measured. Crown heel length will be measured using infantometer. All infection prevention,

precaution standards were used during the time of measurement. Standard precautions were also applied for measuring equipment. All the measurements were taken within 24 hours of birth. After collection of data appropriate statistical test was applied.

**Statistical Analysis:**

SPSS ver.20 was used to analyse data. Data were examined for normality. We used the chi-square test and Fischer's exact test for categorical variables. Independent student t-test was used for continuous variables, as appropriate. A P value of <0.05 was considered statistically significant and all tests were 2-tailed.

**Results:**

The AUC score based on ROC curve was 0.90 (Table 2, fig 1). The optimal cut-off foot length for full term categorization was 75.2 mm. The identification of preterm newborns with foot length < 75.2mm had a sensitivity of 92.0%,which means that 92% of preterm newborns (<37 weeks) can be detected by a foot length examination, specificity of 90.0% means that there is a 90% improbability of full term gestational age <37 weeks) in newborns who have a foot length <75.2mm. The positive predictive value was 90.2%, which means that for newborn foot length <75.2 mm, the possibility of preterm gestational age was 90.3% In addition, negative predictive value was 91.84%, which means that for foot length < 75.2 mm, the possibility of full term newborn <37 weeks) was 91.84%.

**Table 1: Correlation between GA (wk.) and FL (mm), HC, length and weight of baby**

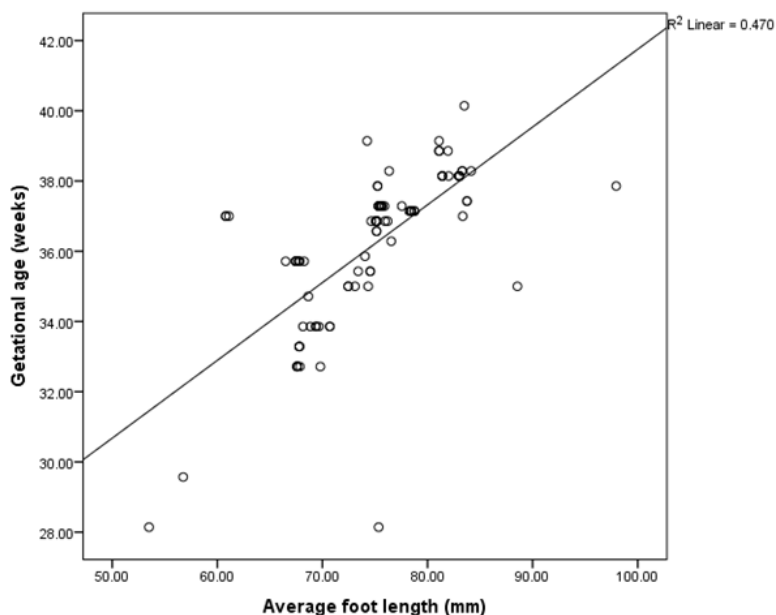|  | Gestational age (weeks) | |
|---|---|---|
|  | r value | p value |
| Birth weight | 0.838 | <0.001 |
| Head circumference | 0.706 | <0.001 |
| Length of baby | 0.671 | <0.001 |
| Foot length (mm) | 0.686 | <0.001 |

**Figure 1 : Scatterplot showing correlation between gestational age and foot length**

**Table 2: Association between GA (wk.) and FL (mm)**

| G age (weeks) | No. of Newborns | Foot length (mm) | | Length (cm) | | Head circumference (cm) | |
|---|---|---|---|---|---|---|---|
| | | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** |
| 28 | 2 | 64.42 | 15.450 | 36.00 | 0.00 | 27.00 | 0.00 |
| 29 | 1 | 56.75 | 0.00 | 38.00 | 0.00 | 28.00 | 0.00 |
| 32 | 8 | 67.90 | 0.770 | 36.00 | 0.00 | 30.00 | 0.00 |
| 33 | 10 | 69.02 | 1.132 | 44.60 | 4.789 | 29.20 | 1.735 |
| 34 | 1 | 68.65 | 0.00 | 41.00 | 0.00 | 30.00 | 0.00 |
| 35 | 17 | 71.63 | 5.351 | 41.71 | 3.869 | 30.70 | 1.829 |
| 36 | 11 | 75.39 | 0.576 | 44.73 | 1.272 | 33.09 | 0.301 |
| 37 | 29 | 76.49 | 7.043 | 47.52 | 3.439 | 32.75 | 2.06 |
| 38 | 18 | 82.13 | 1.702 | 47.67 | 1.283 | 33.38 | 0.607 |
| 39 | 2 | 77.67 | 4.843 | 46.50 | 0.707 | 33.00 | 1.41 |
| 40 | 1 | 83.50 | .00 | 49.00 | 0.00 | 34.00 | 0.00 |

**Discussion:**

In our study we enrolled total 100 newborn, out of which 51 were males and 49 females. There was no significant baseline characterstics difference between males and females ( p value <0.05 ) . There were 50 preterms and 50 terms newborns .Based on birth weight , three newborns were very low birth weight (VLBW) of less than 1500 gms, 40 were low birth weight(LBW) less than 2500gm and 57 newborns <2500gm of weight .The mean footlength of male and female newborn was 75.33mm &amp; 74.04 mm respectively. The optimal cut off value of footlength for identifying preterm(<37 weeks ) newborn was 75.2 mm .We found

significant correlation between gestational age of newborn and footlength measured within 24hrs of birth.

Preterm newborn birth remains a serious problem and was the highest cause of death in children less than 5 years of age in the last 10 year [18-20] .One of the first steps to assist these newborns is inventing an inexpensive, fast, easy to use, and acceptable screening tool for health workers to identify at-risk babies. In this study we have shown that, measurement of newborn foot length should be used as a screening tool to identify premature newborns and allow proper early intervention to enhance their survival [21, 22].

Foot length had high sensitivity and specificity in identifying preterm newborns, making it a reliable tool in a rural setting [23]. In the present study, it was found that foot length had a statistically significant strong classification power to categorize preterm and term newborns. The diagnostic performance of foot length measurement was very strong with AUC of 0.90 (95% CI 0.82-0.97). Our finding is higher than other studies conducted in Vietnam by Nabiwemba Eet al, in Nepal by Ashish et al, in Surakarta by Marchant T et al, while lower than study conducted in Uganda with AUC score based on ROC curve 0.88, 0.683, 0.868 and 0.95, respectively [20, 21, 24, 25]. In the our study, the mean foot length of newborn subjects was found to be 74.70 mm (95% CI 7.32–7.50 cm) which is similar to studies conducted in Vietnam (7.4), Eastern India (7.33) and Aurangabad-India (7.42) [24, 26, 27]; but lower than reported from Uganda, Nepal, and Bengaluru [20, 21, 23]. The difference in mean foot length could be due to genetic, racial or regional (geographic) factors. It could also be due to a difference in measuring instruments (stiff transparent plastic ruler) and measuring techniques used in those studies while we use electronic vernier caliper for measurement of foot length.

There was no statistically significant difference (p <0.05) in mean foot length measurement between male and female newborn subjects. This finding is simiar to the studies conducted in Surakarta and South Africa [25, 28]. The present study has shown that the optimal cutoff point of foot length was found to be 75.2mm with a sensitivity of 92% and specificity of 90% . However, foot length cut- point values vary by setting which were 7.1–8.0 cm in studies conduted in Asia [21, 24–26, 29] and 7.6–8 cm in Africa [20, 22, 28], respectively. A study conducted in Vietnam found that a foot length ≤7.3 cm taken at birth was 80% sensitive and 81% specific in identifying premature (<37 weeks) newborns which is comparable with the cutoff point found in the present study [24]. This finding is also comparable with the study done in Bengaluru reporting the cut-off point for FL of ≤ 7.4 cm with 98.81% sensitivity and 79.09% specificity for identifying preterm Newborns [22]. Studies conducted in Nepal and India revealed that the operational cut-off for determining preterm newborns was 7.8 cm and 7.75 cm, respectively [21, 26]. This is higher than the cutoff point found in the present study (7.35 cm). A study performed in Surakarta showed that the optimal cutoff foot length for full-term categorization was 7.1 cm with a sensitivity of 75% and specificity of 98.1% which is lower than the cut-off point in the present study [25]. Recent African studies conducted in southern Tanzania and Uganda have used foot lengths of ≤8 cm and ≤7.6 cm with sensitivity and specificity of 93% (95%CI 82%-99%) and 58% (95%CI 53%-62%), and 96% (95%CI 82–100) and 76% (95% CI 73–79), respectively, to identify preterm newborns. These cutoff values are much higher than the present study [20, 22]. The cut-off point of foot length in Indore (7.37 cm) is consistent with the present finding [29]. The difference in operational cutoff foot

length value could be due to genetic, racial, regional (geographic) and measuring instrument variation.

In the present study, a statistically significant strong positive correlation was found between gestational age and foot length (r = 0.865 (95% CI 0.832–0.895) and p-value = 0.000). This finding is strongly supported by other studies conducted in Eastern India, Bengaluru, South Africa, and India, where foot length and gestational age had a strong positive correlation [23, 26, 28, 30]. However, a report in Surakarta showed a weaker statistically significant correlation (r = 0.533; P = 0.000) [25]. Accordingly, studies in Belgaum, Indore, north India, and Nagpur observed a significant strong positive correlation between FL and GA with r -value 0.988, 0.99, 0.975, and 0.960 where the coefficient of correlation is greater than the current study [29, 31–33] A linear association was obtained when FL was plotted against GA, which is comparatively similar to the linear curve obtained in the Streeter's. An intercept between the 2 regression lines was also close to the threshold FL of 7.35. [34,35]

Different type of equipments were used to measure footlength of newborns in various studies across the world , and results found to be similar in all the studies. The footlength values measured in all the studies were comparable. The inter study variation is very less, so footlength can be used as valuable, inexpensive anthropometric tool for identifying high risk newborns especially in rural settings with low resources fpr their early identification for optimal management and earlier refferal.

## Limitations:

The present study had several limitations. First, present study had a relatively small number of patients were included. More multicentric studies with larger sample size may prove a better utility of this intervention.. A limitation of this study

was our focus on foot length to predict preterm and full term newborns who were appropriate-for-gestational age (AGA), to the exclusion of IUGR

and large-for-gestational age babies. our study was done in a hospital based setting, so the prevalence of preterm was higher than in a community setting.

**Conclusions:** In conclusion, newborn foot length can be used to predict gestational age. Longer newborn foot length is indicative of higher gestational age. The optimal cut-off point for diagnosing full term babies was 7.52 cm. Foot length <7.52 cm can be used to diagnose preterm babies. Newborn foot length is a reliable anthropometric measurement to diagnose preterm babies.

## Acknowledgement

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