## Original Research Article

# A study of correlation of foot length and new Ballard score in determining the gestational age of newborns

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### ABSTRACT

**Background:** Gestational age (GA) estimation plays a vital role in obstetric, perinatal and neonatal care. Foot length (FL) measurement can serve as a simple, easy and cost effective parameter for estimating GA. The aim of this study was to determine correlation between foot length of new born and GA by new Ballard score and forming a percentile chart if a positive correlation was found.
**Methods:** GA assessment of newborns born in our hospital was done by new Ballard score within 24 hours of life. FL was measured using vernier caliper. Neonates were classified as pre term, term and post term and also grouped as small for GA (SGA), appropriate for GA (AGA) and large for GA (LGA).
**Results:** FL measurement was strongly correlating with GA assessment by new Ballard score, with overall correlation coefficient r=0.897 (p<0.001). FL increased as GA increased. Strong positive correlation was seen in pre term and term newborns. The cut-off foot lengths for identifying preterm and early preterm neonates were 73.14 mm (diagnostic accuracy 88.4%) and 68.49 mm (diagnostic accuracy 95.3%), respectively.
**Conclusions:** Strong positive correlation of foot length with GA by new Ballard score was obtained and a percentile chart of foot length for each GA was formed, with mean and standard deviation. This can serve as a simple and quick tool, requiring less expertise for GA assessment.

**Keywords:** Newborn, Gestational age, Foot length, New Ballard score, Correlation

## INTRODUCTION

GA is an important factor in determining the survival and outcome of the new born as well as for various medico-legal, epidemiological and research purposes. The GA determined at the time of birth, helps in predicting the probable morbidities that the neonate is likely to suffer from as a consequence of his maturity. This gives scope for early identification of such morbidity, prompt treatment and improved outcome. Hence, management of a newborn baby starts with knowing the GA.

India newborn action plan (INAP), launched in June 2014, aims at attaining single digit neonatal mortality rate (NMR) by 2030. Preterm birth complications contributes to 35% of the neonatal deaths in India and also globally.[1,2]

Early identification of preterm babies will help in early and appropriate care and hence their mortality can be reduced. In India, according to National family health survey-4 (NFHS-4) (2015-2016), 78.9% of deliveries were institutional and the remaining were non-institutional and only 41% of neonates underwent any checkup within 24 hours after birth. Hence, there is a need to develop a simple, inexpensive and cost effective method to identify highly vulnerable preterm newborns soon after birth.[3,4]

GA assessment is important medico legally too. GA has to be calculated accurately in cases of foeticide, surreptitious disposal of babies, still births and spontaneous or induced abortions. Doctors are expert witnesses in the court of law and they need to give an opinion regarding the viability of the baby, for which GA assessment is required.[5]

Estimation of GA using FL measurement can serve as a single parameter that is simple, cost effective, easy and requires minimal expertise. FL measurement can be easily taught to peripheral health workers, who can use it in a resource poor setting to screen for prematurity and plan early referral. It can also be carried out in extremely sick neonates who require minimal handling, who are sedated or paralysed, who are on multiple intravenous lines or on ventilator and even in still-born. A standardized chart involving foot length for estimating GA is not yet available.

Hence this study for finding the correlation of FL and GA and also forming a percentile chart was carried out.

## METHODS

This cross-sectional analytical study was carried out on newborns born in Rajiv Gandhi government women and children hospital, Puducherry, after approval from the scientific and ethical committee from September 2017 to May 2018. The sample size was calculated using Open Epi software, based on findings of previous studies and reports by WHO, with 80% power and 95% confidence interval.[6-8] The sample size was 380, selected by random sampling with 10% anticipated drop outs.

All live newborns less than 24 hours of life who were clinically stable were included and those syndromic or hypotonic, critically ill, paralyzed or sedated, newborns with external deformities, birth asphyxia and symmetrical IUGR calculated by Ponderal index were excluded. Neonates were examined by new Ballard score within 24 hours of life, for GA assessment. FL was measured using vernier caliper, between the most prominent posterior point of the heel and the tip of the longest toe in the right foot, with an accuracy of one-tenth of a millimetre. Birth weight was recorded using an electronic weighing scale with an accuracy of ±10 grams. Crown heel length was measured by using an infantometer with an accuracy of ±0.5 cm. These parameters were used to identify symmetrical IUGR babies using Ponderal index for exclusion.[9]

Neonates were grouped as preterm (GA less than 37 weeks), term (GA of 37 weeks to 41 6/7 weeks) and post term (GA of 42 weeks or more) as per standard definitions.[10] Using Fenton's chart, neonates were also grouped as SGA, AGA and LGA.[10]

Data was analysed using SPSS software version 22.0. Association between GA by new Ballard score (in weeks) and right FL (in mm) was assessed by calculating Pearson's correlation coefficient. The utility of right foot length in predicting preterm/term and also for newborns above and below 34 weeks of GA was assessed by receiver operative curve (ROC) analysis. P<0.05 was considered statistically significant.

## RESULTS

In this study, out of 380 neonates, 64.5% were term, 28.9% were pre term and 6.6% were post term out of which 57.9% belonged to term AGA subgroup. The genders of neonates studied were comparable between the groups (Table 1).

The GAs of the study group ranged from 29 weeks to 42 weeks, foot length ranged from 57.8 mm to 86.4 mm and birth weight ranged from 1.12 kgs to 4.43 kgs (Table 2).

There was a strong positive correlation between GA assessment by new Ballard score and right foot length overall (r value: 0.897, p value: <0.001) and also in pre term and term groups (Table 3).

In the subgroup analysis it was found that there was strong positive correlation between GA assessment by new Ballard score and foot length in preterm/AGA, preterm/LGA and term/SGA and groups and moderate positive correlation in preterm/SGA and term/AGA groups. In post term group, correlation could not be calculated either, because of small sample size or only one value of intended variable for statistical analysis (Table 4).

Further analyses were carried out by ROC to find the cut-off foot length for distinguishing between preterm and term gestation and also between neonates above and below 34 weeks gestation. The right foot length (mm) had excellent predictive validity in predicting in preterm/term gestation, as indicated by the area under the curve of 0.938 (95% CI 0.914 to 0.963, p value <0.001). (Figure 1).

In pre term group, 80.9% neonates were below and 19.1% neonates were above the cut-off right foot length level of 73.14 mm. In term group, 8.5% neonates were below and 91.5% neonates were above the cut-off right foot length level of 73.15 mm. The difference in the proportion of right foot length level between preterm/term neonates was statistically significant (p value <0.001) (Table 5).

The right foot length of 73.15 mm had sensitivity of 80.9% (95% CI 73.55% to 88.2%), specificity of 91.5% (95% CI 44.44% to 79.8%) and diagnostic accuracy of 88.4% (95% CI 85.02% to 91.6%) in predicting preterm and term gestation of neonates.

**Table 1: Demographic data of the neonates in the study (n=380).**

| Demographics | N | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Gender** | | | | | | | | | |
| Male | 188 | | | | | | | | |
| Female | 192 | | | | | | | | |
| **Gestational maturity and subgroups** | Pre-term | | | Term | | | Post-term | | |
| | 110 | | | 245 | | | 25 | | |
| | SGA | AGA | LGA | SGA | AGA | LGA | SGA | AGA | LGA |
| | 10 | 96 | 4 | 23 | 220 | 2 | 3 | 22 | 0 |

**Table 2: Descriptive analysis of GA, foot length and birth weight of the study population (n=380).**

| Parameters | Mean ±SD | Median | Min | Max | 95% C.I | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| **GA by new Ballard score (weeks)** | 37.48±2.29 | 37.00 | 29.00 | 42.00 | 37.25 | 37.72 |
| **Right foot length (mm)** | 75.11±4.88 | 75.85 | 57.80 | 86.40 | 74.62 | 75.60 |
| **Birth weight (kg)** | 2.8±0.57 | 2.73 | 1.12 | 4.43 | 2.75 | 2.86 |

**Table 3: Correlation between GA by new Ballard score and right foot length (n=380).**

| Parameters | Pearson correlation coefficient (r) | P value |
|---|---|---|
| **Over all** | 0.897 | <0.001 |
| **Pre term** | 0.792 | <0.001 |
| **Term** | 0.705 | <0.001 |
| **Post term** | * | * |

*since all the newborns in post term group had 42 weeks as GA no correlation could be computed.

**Table 4: Correlation between right foot length and GA assessment by new Ballard score in various subgroups of maturity and growth (n=380).**

| Subgroups | Pearson's correlation coefficient (r) | P value |
|---|---|---|
| **Pre term/AGA (n=96)** | 0.830 | <0.001 |
| **Term/AGA (n=220)** | 0.749 | <0.001 |
| **Post term/AGA (n=22)** | * | * |
| **Pre term/SGA (n=10)** | 0.765 | 0.010 |
| **Term/ SGA (n=23)** | 0.835 | <0.001 |
| **Post term/SGA (n=3)** | * | * |
| **Pre term/ LGA (n=4)** | 0.998 | 0.002 |
| **Term/LGA (n=2)** | * | * |

**\*Note: correlation could not be calculated either, because of small sample size or only one value of intended variable for statistical analysis.

**Table 5: Comparison of right foot length level with pre term/term (n=380).**

| Right foot length level (mm) | Pre term/term | | Chi-square | P value |
|---|---|---|---|---|
| | Pre term | Term | | |
| **Low (up to 73.14)** | 89 | 23 | 197.039 | <0.001 |
| **High (73.15 and above)** | 21 | 247 | | |

**Table 6: Comparison of right foot length level with neonates above and below 34 weeks of gestation (n=380).**

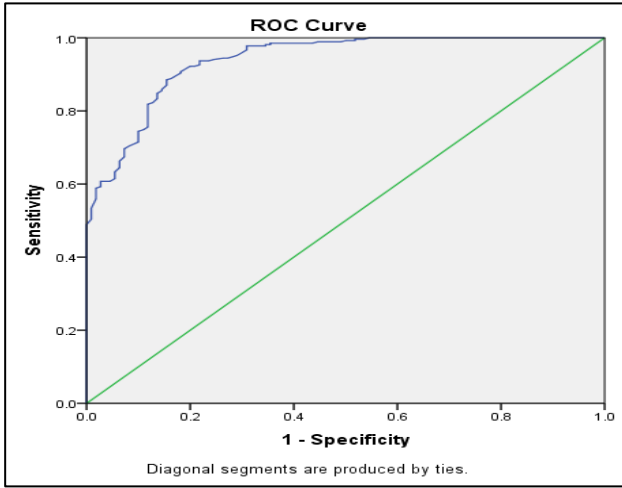| Right foot length (<68.5 mm) | GA 34 weeks | | Chi square | P value |
|---|---|---|---|---|
| | Up to 34 weeks | Above 34 weeks | | |
| **Low (up to 68.49 mm)** | 26 | 13 | 198.571 | <0.001 |
| **High (68.50 mm and above)** | 5 | 336 | | |

**Figure 1: Predictive validity of right foot length in predicting pre term/term neonates (n=380).**

Similarly, the right foot length (mm) had excellent predictive validity in predicting GA below and above 34 weeks, as indicated by the area under the curve of 0.983 (95% CI 0.970 to 0.997, p value <0.001) (Figure 2).

In the group of neonates less than 34 completed weeks of gestation, 83.9% neonates were below and 16.1% neonates were above the cut-off right foot length level of 68.49 mm. In the group of neonates belonging to 34 weeks gestation and above, 3.7% neonates were below and 96.3% neonates were above the cut-off right foot length level of 68.5 mm. The difference in the proportion of right foot length level in neonates belonging to GA

below and above 34 weeks was statistically significant (p value <0.001) (Table 6).
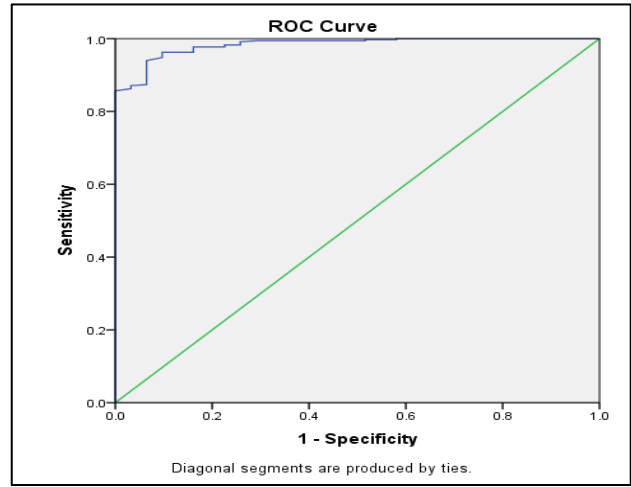


**Figure 2: Predictive validity of right foot length in predicting GA up to 34 weeks and above (n=380).**

The right foot length of 68.49 mm had sensitivity of 83.9% (95% CI 70.96% to 96.8%), specificity of 96.3% (95% CI 94.32% to 98.3%) and diagnostic accuracy of 95.3% (95% CI 93.13% to 97.4%) in predicting GA of neonates below and above 34 weeks.

With the data collected and analysed, a percentile chart of foot length for each GA including mean and standard deviation was obtained which can be used in prediction of GA of newborns using foot length (Table 7).

**Table 7: Mean, standard deviation and percentile chart of right foot length (mm) for corresponding GA (in weeks) (n=380).**

| GA by new Ballard score (in weeks) | Foot length | Percentiles of foot length | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Mean±SD (in mm) | 5th | 10th | 25th | 50th | 75th | 90th | 95th |
| 30.0 | 60.35±0.63 | 59.900 | 59.900 | 59.900 | 60.350 | - | - | - |
| 32.0 | 64.82±1.90 | 62.500 | 62.500 | 62.750 | 65.900 | 66.350 | - | - |
| 33.0 | 65.48±1.59 | 63.800 | 63.800 | 64.100 | 65.250 | 66.900 | - | - |
| 34.0 | 67.05±2.39 | 62.200 | 63.880 | 65.175 | 66.800 | 68.500 | 71.250 | - |
| 35.0 | 69.11±2.28 | 65.640 | 66.800 | 67.700 | 68.700 | 70.400 | 72.640 | 75.020 |
| 36.0 | 72.57±2.53 | 68.610 | 69.480 | 70.350 | 72.300 | 74.800 | 76.360 | 76.690 |
| 37.0 | 74.76±2.01 | 71.070 | 72.000 | 73.400 | 75.000 | 76.200 | 76.960 | 77.620 |
| 38.0 | 76.52±1.96 | 72.055 | 74.010 | 75.500 | 76.950 | 77.625 | 78.890 | 79.925 |
| 39.0 | 78.39±1.19 | 76.665 | 76.890 | 77.550 | 78.350 | 79.050 | 79.470 | 81.150 |
| 40.0 | 79.15±1.84 | 76.320 | 76.960 | 77.600 | 78.700 | 80.600 | 82.180 | 82.800 |
| 41.0 | 80.66±2.14 | 77.700 | 78.400 | 78.850 | 80.000 | 82.325 | 84.330 | - |
| 42.0 | 83.22±2.42 | 78.790 | 79.180 | 81.450 | 83.300 | 85.500 | 86.140 | 86.340 |

**DISCUSSION**

FL has been an important parameter in many research involving foetal and neonatal GA estimation. The

research in this field spread over a century, with various studies revalidating the findings by Streerer et al (n=704), who conducted postmortem study of foetal foot length and its correlation with GA, revealed positively

correlating findings which were tabulated for future research and use in clinical practice.[11]

Studies on foetal FL measured antenatally by ultrasound and postnatally in neonates were done and correlated with GA. One such study was done by Mercer et al (n=223) and measurements performed between 11 and 43 weeks of gestation, concluded that correlation between antenatal and postnatal foot length was conclusive of the fact that it was a reliable parameter for estimation of GA.[12] Most of the studies measured foot length by calliper since it was very accurate and precise.[13,14]

Postnatal measurement of FL and its role in replacing other methods of assessing GA has been gaining importance and many studies have been done in this field, since this doesn't require medical expertise thereby decreasing the work load on doctors.

### *Demographic and descriptive data*

The sample size and percentage of male and female neonates recruited in this study were comparable to various studies done earlier. Similar to this study, the subgroup analysis of neonates in most of the previous studies, showed a preponderance of term neonates and most of them belonged to AGA group as well. The range and average GA by new Ballard score, FL and birth weight of neonates were similar to study by Srinivasa et al.[15] In the present study, further grouping based on both maturity and growth showed that majority of neonates belonged to term AGA followed by preterm AGA which was similar to the study by Gavhane et al.[16]

### *Correlation of foot length with new Ballard score*

Significant positive correlation between right FL and new Ballard score to estimate GA was found in pre term and term babies with correlation coefficient of 0.792 and 0.705 respectively. Correlation was higher in preterm group compared to term, similar to the study by Rakkappan et al who also obtained higher correlation in preterm group (r=0.756) compared to term (r=0.614).[17] The overall correlation between right FL and new Ballard score to estimate GA was found to be strongly positive with a correlation coefficient r=0.897 (p<0.001) which was very similar to many other studies. A study by Wyk et al and Kumar et al showed correlation of 0.887 and 0.886 respectively, closer to what was obtained in this study.[14,18]

### *FL cut-off level for identification of pre term and term babies*

For identification of preterm neonates , those less than 37 completed weeks, a cut-off foot length of 73.14 mm was obtained which was close to the value obtained in a study by Thi et al (cut-off foot length=73.0 mm) and Srivastava et al (cut-off foot length=73.7 mm).[19,20]

### *FL cut-off level for identification of neonates below and above 34 weeks*

In order to identify extreme premature newborns, another operational cut-off to identify newborns less than 34 weeks was obtained by receiver operation curve. This was clinically important since such neonates have immature lungs, were prone for serious infections, have feeding issues. A cut-off foot length of 68.49 mm was obtained, which was similar to the cut-off length of 68.0 mm obtained in the study by Pratinidhi et al.[21]

### *Correlation of FL and new Ballard score in subgroups*

Correlation between right FL and various subgroups of maturity and growth were analysed. Significant correlation was obtained in preterm AGA, term AGA, pre term SGA, term SGA and pre term LGA groups. Analysis could not be done in post term AGA, post term SGA and term LGA group because of only one value of intended variable and because of small sample size respectively. A similar analysis done by Sateesha et al showed, FL strongly correlating with GA in pre term AGA and term AGA, with correlation coefficient of 0.860 (p<0.001) and 0.371 (p<0.001), respectively and weakly correlating in pre term SGA, term SGA and term LGA, with correlation coefficients of 0.598 (p=0.005), -0.158 (p=0.403) and 0.137 (p=0.707) respectively.[22] In a study by Saroj et al strong correlation was seen in preterm AGA, with correlation coefficient of 0.42 (p<0.001), but no correlation in term SGA, r=-0.016 (p<0.935).[23]

### *Percentile chart*

Since a strong positive correlation between right FL and new Ballard score to estimate GA was obtained, a percentile chart, similar to the one by Yadav et al was formed, which included 5th, 10th, 25th, 50th, 75th, 90th, 95th and 97th percentiles of foot length for GAs ranging from 30 to 42 weeks.[24] This will prove beneficial as a simple, quick and cost effective tool for estimation of GA of a neonate.

### CONCLUSION

FL was found to be strongly correlating with GA assessment by new Ballard score, with overall correlation coefficient r=0.897 (p<0.001). Strong positive correlation was seen in pre term and term newborns, more in preterm neonates. The cut-off FL for identifying preterm neonates (<37 weeks of gestation) was 73.14 mm, with a diagnostic accuracy of 88.4%. The cut-off FL for identifying early pre term neonates (<34 weeks of gestation) was 68.49 mm, with a diagnostic accuracy of 95.3%.

Strong positive correlation between FL and GA assessment by new Ballard score was found during sub group analysis in preterm AGA (r=0.830), term SGA

(r=0.835) and pre term LGA (r=0.998). Moderate positive correlation was seen in term AGA (r=0.749) and pre term SGA group (r=0.765).

A percentile chart for the mean FL for each GA was created, which can be used in daily practice to determine their GA with ease. Foot length measurement was found to be a simple, easy and cost-effective tool for early detection and management of high-risk newborns in a resource poor setting as well as in a busy tertiary care setting.

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