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Original Article

Diagnostic value of newborn foot length to predict gestational age

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Abstract

Background 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. Newborn foot length is an anthropometric measurement which is easy to perform, inexpensive, and potentially efficient for predicting gestational age.

Objective To analyze the diagnostic value of newborn foot length in predicting gestational age.

Methods This diagnostic study was performed between October 2016 and February 2017 in the High Care Unit of Neonates at Dr. Moewardi General Hospital, Surakarta. A total of 152 newborns were consecutively selected and underwent right foot length measurements before 96 hours of age. The correlation between newborn foot length to classify as full term and gestational age was analyzed with Spearman's correlation test because of non-normal data distribution. The cut-off point of newborn foot length was calculated by receiver operating characteristic (ROC) curve and diagnostic values of newborn foot length were analyzed by 2 x 2 table with *SPSS 21.0* software.

Results There were no significant differences between male and female newborns in terms of gestational age, birth weight, choronological age, and newborn foot length (P>0.05). Newborn foot length and gestational age had a significant correlation (r=0.53; P=0.000). The optimal cut-off newborn foot length to predict full term status was 7.1 cm. Newborn foot length below 7.1 cm had sensitivity 75%, specificity 98%, positive predictive value 94.3%, negative predictive value 90.6%, positive likelihood ratio 40.5, negative likelihood ratio 0.25, and post-test probability 94.29%, to predict preterm status in newborns.

Conclusion Newborn foot length can be used to predict gestational age, especially for the purpose of differentiating between preterm and full term newborns. **[Paediatr Indones. 2017;57:181-6; doi: http://dx.doi.org/10.14238/pi57.4.2017.181-6]**.

Keywords: *preterm; foot length; gestational age; newborn*

Gestational age is a major determinant of newborn prognosis. Newborns are categorized as preterm, full term, or post-term neonates. These categories refer to the neonates' gestational age grouping: born at < 37 weeks, at 37 to 41 weeks, or at > 42 weeks, respectively. Early identification of gestational age within 48 hours of birth, especially in differentiating preterm from full term newborns born at home or in remote areas, is a major priority for researchers and public health practitioners in order to reduce global mortality from preterm birth. Mortality can be prevented if preterm newborns are identified earlier and treated with simple interventions such as skin-to-skin contact or kangaroo mother care (KMC), early

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breastfeeding, as well as early infection prevention and treatment.[1-4] Identification of preterm newborns is difficult in community settings, especially in remote areas, where maternal labor is assisted by unskilled health workers or unlicensed midwives. As these birth assistants are unable to predict gestational age, half of all newborns in these settings have unknown gestational age.[5]

Early studies related to newborn anthropometric parameters were performed to identify the correlation between anthropometric cut-off points and birth weight, as well as gestational age. Currently, newborn foot length is studied as an alternative anthropometric measurement to detect low birth weight and preterm status, as no special skill is needed to perform this measurement and preterm newborns are not at risk to hypothermia because of the measurement. Newborn foot length is an easy, quick, and efficient measurement for preterm, critically ill newborns. This measurement technique is not influenced by either subcutaneous fat or biological sex.[6,7,8] This study aimed to analyze the diagnostic value of newborn foot length in predicting gestational age.

Methods

This cross-sectional study was performed in Dr. Moewardi General Hospital, Surakarta from October 2016 to February 2017. Subjects were newborns admitted to the High Care Unit (HCU) of Neonates. Neonates aged 0 to 96 hours whose parents provided written, informed consent were included in this study. Newborns with congenital anomalies of the feet, intrauterine growth restriction (IUGR), extremely low birth weight (birth body weight < 1,000 grams), extremely preterm (gestational age < 28 weeks old), severe asphyxia, or large for gestational age were excluded from this study. Subjects were consecutively collected and the minimum required sample size was calculated by diagnostic test sample formula.

Subjects' right foot lengths were measured twice from heel to big toe, with an iron ruler, calibrated to 0.1 cm precision. The reference standard for gestational age was the *New Ballard Score* (NBS) measurement.[9-12]Measurements were conducted by different resident physicians who were in charge of the HCU. Researchers were blinded to these measurements. The study was approved by the Ethics Committee of the Faculty of Medicine at University of Sebelas Maret, Surakarta, and the Ethics Committee of Dr. Moewardi General Hospital.

The Kolmogorov-Smirnov test was used to assess types of distribution of the investigation parameters. Non-normally distributed data were expressed as median and their corresponding interquartile ranges. Categorical variables were expressed as frequencies and percentages or relative values. Baseline characteristics of subjects (gestational age, birth weight, chronological age, and newborn foot length) were expressed as median values and compared between males and females. Data were analyzed by Chi-square test (categorical data) and Mann-Whitney test (numerical data) using *SPSS 21.0* software for Windows. The correlation coefficient to measure the power of correlation between the independent and dependent variables was analyzed by Spearman's correlation test because of non-normal distribution data. The optimal cut-off newborn foot length to predict gestational age was analyzed by ROC curve. Area under the curve (AUC) was used to assess the power of diagnosis. Diagnostic values such as sensitivity, specificity, positive and negative predictive values, as well as positive and negative likelihood ratios were assessed by 2 x 2 table. Diagnostic ability of newborn foot length was considered to be good for diagnostic parameter > 80%. Reliability of the tool was analyzed by α-Cronbach coefficient (reliable for coefficient > 0.7), while inter-observer variation was analyzed with intraclass correlation coefficient (ICC) (good for ICC value > 0.8) and ANOVA test (good validity for $P > 0.05$).

Results

A total of 152 subjects enrolled in this study. Subjects' baseline characteristics were not significantly different between males and females ($P>0.05$) (**Table 1**). The AUC score based on ROC curve was 0.868 ($P<0.01$) (**Table 2, Figure 1**). The optimal cut-off foot length for full term categorization was 7.1 cm. A comparison of newborn foot length and NBS is shown in **Table 3**. Diagnostic values were calculated based on this table. The identification of preterm newborns with foot length < 7.050 cm had a sensitivity of 75.0%,

which means that 75.0% of preterm newborns (<37 weeks) can be detected by a foot length examination, and a specificity of 98.1% means that there is a 98.1% improbability of full term gestational age (> 37 weeks) in newborns who have a foot length <7.1 cm.

The positive predictive value was 94.3%, which means that for newborn foot length <7.1 cm, the possibility of preterm gestational age was 94.3%. In addition, negative predictive value was 90.6%, which means that for foot length > 7.1 cm, the possibility of full term newborn (> 37 weeks) was 90.6%.

Table 1. Baseline characteristics of subjects

Baseline	Gender		Total	P value
	Males (n=72)	Females (n=80)		
NBS*, n(%)				
< 37 weeks	18 (40.9)	26 (59.1)	44 (28.9)	0.309
≥ 37 weeks	54 (50.0)	54 (50.0)	108 (71.1)	
Chronological age**, n(%)				
0 day	45 (62.5)	46 (57.5)	91 (59.9)	0.541
1 day	25 (34.7)	31 (38.8)	56 (36.8)	
2 days	2 (2.8)	2 (2.5)	2 (2.6)	
3 days	0	1 (1.3)	1 (0.7)	
Median NBW** (range)	36 (20-41)	36 (20-41)	36 (20-41)	0.739
Median foot length** (range), cm	7.5 (5.4-9.0)	7.4 (5.5-8.6)	7.4 (5.4-9.0)	0.282
Median birth weight** (range), grams	3,000 (1,000-4,000)	2,700 (1,150-3,900)	2,875 (1,000-4,000)	-0.084

Note: Categorical variables (gestational age and chronological age) were stated by percentage and analyzed by Chi-square test. Numerical variables (New Ballard Score, foot length, and birth body weight) were stated in median (minimum – maximum) because of non-normal data distribution, and were analyzed by Mann-Whitney test. * categorical variables; ** numerical variables.

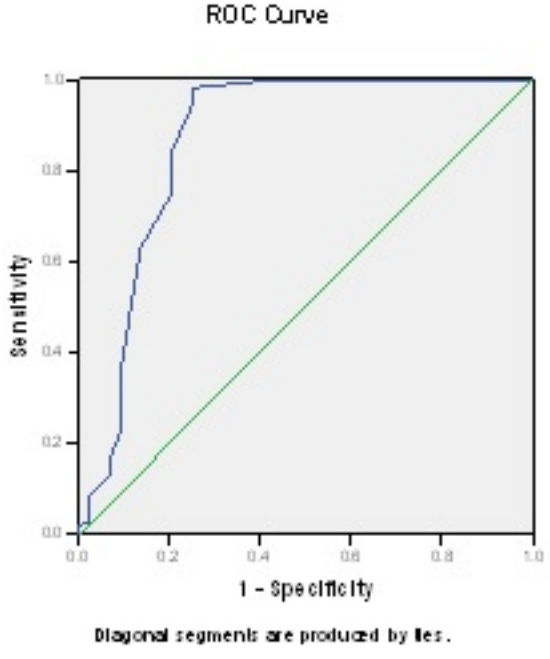

Figure 1. REceiver operating characteristic (ROC) curve.

Table 2. The optimal newborn foot length cut-off point based on New Ballard Score as the reference standard

AUC	Sensitivity	1-Specificity	Cut-off value	P value
0.868	0.981	0.250	7.050	0.000

The positive likelihood ratio (LR+) value was 40.5, indicating that the probability of preterm newborns having a foot length <7.1 cm was 40.5 times greater than foot length > 7.1 cm. In addition, the negative likelihood ratio (LR-) was 0.225, indicating that the probability of preterm newborns having a foot length > 7.1 cm was 0.225 times less than <7.1 cm (**Table 4**).

The correlation analysis between gestational age and newborn foot length is shown in **Table 5**. In male and female newborns, gestational age and foot length had a significant correlation (males: r=0.376; P=0.000; females: r=0.633; P=0.000). Furthermore, regardless of sex, gestational age and foot length had a significant correlation (r=0.533; P=0.000).

Newborn foot length measurements were performed twice by two different physicians. We calculated reliability value of this measurement

with alpha coefficient score. The result was good (r=0.997). ANOVA test also revealed that inter-rater assessment was not significantly different (P=0.903), and inter-class correlation of rater reliability was good (r=0.994).

Table 5. Spearman's rank correlation test results

New Ballard Score	Foot length		
	Males	Females	All subjects
Correlation coefficient	0.376	0.633	0.533

Table 4. Diagnostic study results

Measurement	Diagnostic test					
	Sensitivity	Specificity	PPV	NPV	LR+	LR-
Foot length	0.75	0.98	0.943	0.906	40.5	0.255

Discussion

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 years.[1-4] 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. Various methods of anthropometry can be performed to diagnose preterm status in newborns, such as the circumferences of the chest, abdomen, head, and calf. However, these measurements are influenced by subcutaneous fat and biological sex. Such measurements also take longer to perform, putting these infants at risk of hypothermia.

Our results are consistent with previous research by Marchant *et al*. in southern Tanzania. They reported that foot length of <8 cm on the first day of birth had a 93% sensitivity (95%CI 82 to 99), 58% specificity (95%CI 53 to 62), 15% positive predictive value, and 99% negative predictive value to detect preterm in newborns. The average foot length on the first day was 7.8 (SD 0.4) cm and on the fifth day was 8.1 cm. The mean difference of foot length between the first day and the fifth was 0.2 cm (SD 0.3).[6]

Ashish *et al.* reported validation of foot length measurements with a ruler as an alternative tool for identifying low birthweight and preterm newborns in a low socioeconomic setting. The cut-off point of 7.2 cm for identifying birth weight <2,000 grams had 75.9% sensitivity and 90.3% specificity, while a 7.8 cm cut-off point to identify premature infants had 76.9% sensitivity, 53.9% specificity, 10.6% positive predictive value, and 90.3% negative predictive value. They also compared the use of a ruler, foot print, and tape measurements, and found that a ruler for measuring foot length had the best AUC (0.683) compared to the other means (foot print 0.680 and tape measure 0.598).[9] Another community-based study by Marchant *et al.* reported on the reliability of the tool to measure newborn foot length. They reported that foot length gauges to classify low birth weight babies were moderately reliable when used by volunteers, with a Kappa score of 0.53 (95%CI 0.4 to 0.66).[7]

Mukherjee *et al.* reported that foot length <7.75 cm had 92.3% sensitivity and 86.3% specificity, for preterm newborn identification. For low birth weight, foot length <7.85 cm had 100% sensitivity and 95.3% specificity. For very low birth weight identification (VLBW), foot length <6.85 cm has 100% sensitivity and 94.9% specificity. A correlation coefficient was calculated by Pearson's correlation test. Foot length and gestational age had a good, positive, linear correlation, with a correlation coefficient of 0.869. Foot length and birth weight also had a good, positive correlation, with coefficient of 0.973 in infants and 0.96 in preterm newborns. They also calculated the sensitivity and specificity of two operational cut-off points: <7 cm had 100% sensitivity and 94% specificity in VLBW identification, while <8 cm had 93.5% sensitivity and 75.3% specificity for preterm identification.[14]

Thi *et al.* reported that foot length <7.4 cm had 85% sensitivity, 86% specificity, 86% positive predictive value, and 84% negative predictive value for diagnosing LBW. Foot length <7.3 cm had 80% sensitivity, 81% specificity, 82% negative predictive value, and 79% positive predictive value for preterm newborns. For LBW along with preterm, newborn foot length <7.3 cm had 86% sensitivity, 83% specificity,

77% positive predictive value, and 90% negative predictive value in making the diagnosis.[16] Srivastata et al reported very strong positive correlation between newborn foot length and gestational age with correlation coefficient 0.99.[15]

Different cut-off points in each study and each country suggests that race or country have a role in determining the cut-off point of the foot length. Factors that influence bone growth during pregnancy include genetics, nutrition, placental supply, and hormones. This study alone has never been done in Indonesia. The results of our study are more specific in diagnosing preterm newborns compared to that of previous studies.

Lee *et al.* examined the clinical assessment validity to determine gestational age of newborns in community setting with a total of 1,066 newborns and had results contrasting to ours. They assessed the accuracy of Ballard score, Capurro technique, Eregie technique, Bhagwat technique, and foot length in predicting gestational age compared to the gold standard of ultrasound at gestational age <20 weeks (first and second trimesters). Newborn foot length <75 mm had 64% sensitivity and 35% specificity for diagnosing preterm status in newborns. They concluded that neonatal anthropometry had poor performance to classify preterm newborns (AUC 0.52-0.8), and that newborn foot length was an inaccurate marker for predicting gestational age, due to the high frequency of intrauterine growth restriction newborns in their setting. They did not exclude IUGR and large for gestational age babies, so these criteria influenced the results.[17]

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. Moreover, our study was done in a hospital-based setting, so the prevalence of preterm was higher than in a community setting. As such, our results may have be biased in terms of foot length compared to the general population, in which the incidence of IUGR babies is present.

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 7.1 cm. Foot length <7.1 cm can be used to diagnose preterm babies. Newborn foot length is a reliable anthropometric measurement to diagnose preterm babies.

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Conflict of interest

None declared.

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