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Relationship Between Foot-Length and Gestational Age

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Abstract

Background: Gestational age (GA) is an important factor in the management, decision making, prognostication and follow up of newborn infants. Determination of gestational age, especially within the first 48 hours of birth is therefore invaluable in the assessment of newborns as this information would help in the early detection of high-risk infants such as premature infants, who would require life-saving interventions for survival.

Methods: A cross-sectional, descriptive study conducted over a six-month period (February to July 2020) in Enugu State University Teaching Hospital, Enugu, Nigeria. 235 newborn babies were recruited for the study. Gestational age was determined using the New Ballard Scoring System (NBS). Foot-length (FL) measurements were made from the heel to the tip of the big toe using a hard transparent plastic ruler.

Results: A significant positive correlation existed between newborn foot-length and GA with a correlation coefficient of 0.845. The optimal cut off point of newborn foot-length to predict term was 7.55cm. Newborn foot length of 7.55cm had the sensitivity of 74%, specificity of 94%, positive predictive value of 99% and negative predictive value of 38% for determining gestational maturity. Foot length had a strong power (AUC=0.931) to differentiate between term and preterm newborns.

Conclusion: FL of 7.55cm is a suitable cut-off point to differentiate full-term and preterm babies. FL is thus a good marker of gestational age which can be used where accurate GA assessments and weighing scale are not available to identify high-risk infants.

Keywords: Foot length; Gestational age; Maturity status

Introduction

Gestational age (GA) is an important parameter which is determined in the routine assessment of newborn babies. Determination of gestational age, especially within the first 48 hours of birth is therefore invaluable in the assessment of newborns. It is therefore of utmost importance that a maturity status be assigned to newborn infants as soon as possible after birth. This is because, the earlier this is done, the earlier, at-risk infants such as premature infants are detected, so that life-saving interventions can be instituted. Early trimester ultrasound, the gold standard for GA estimation is largely inaccessible in resource-poor countries.1 In such countries, neonatal units rely on post-natal neonatal scores such as New Ballard Score (NBS) and Dubowitz Examination (DE)) for GA determination. Last Menstrual Period (LMP) is largely inaccurate, and the post-natal scores are cumbersome to perform and require expertise. Evaluation of low-cost tools to accurately identify premature newborns in resource-poor countries is a research priority. Such a tool should be cheap, concise and simple to perform without requiring special expertise, and at the same time be reliable. Foot length measurement, in the determination of GA, fits this description.

The determination of gestational maturity is routinely carried out prenatally and postnatally [1] and this is very vital in the management of newborn babies. This is especially true for babies delivered at home or in remote areas by non-professional medical

workers such as traditional birth attendants (TBAs), such as exists in Nigeria where 50% of deliveries occur outside health facilities [2]. Under these circumstances, determination of gestational maturity is often challenging. This limits and/or delays timely access of the newborn to simple, life-saving interventions such as Kangaroo Mother Care (KMC), early breast feeding and infection prevention and treatment [3]

There are several means of determining gestational maturity [4]. Ultrasound scan (USS) carried out early in pregnancy is the gold standard for gestational age (GA) estimation [5]. This, however, is not readily available in resource-restricted areas such as rural sub-Saharan Africa [5]. Clinical dating using the last menstrual period (LMP), or fundal height can also be done [1]. This, however, is usually inaccurate because the LMP does not take into consideration individual variations in the interval between the LMP onset and conception (7 -25 days) [1]. Birth weight and other anthropometric indices such as Occipito-frontal Circumference (OFC) and Chest Circumferences (CC) are also used [4]. These are however affected by changes in body water, carbohydrate, fat, protein, and mineral levels [4]. This is apart from errors in weighing scales due to poor calibration and observer errors due to parallax [4]. The New Ballard Scoring Scale (NBSS) and Dubowitz Examination (DE) which score infants based on physical characteristics and neurological criteria may underestimate GA in small for gestational age (SGA) babies [6]. With all these limitations, the identification and evaluation of low cost and simple assessment methods to determine gestational maturity has been ranked the number one research priority to reduce global mortality from prematurity and low birth weight [3].

Foot-length measurement has been studied as a tool for determination of gestational maturity [2,7]. In 2012, the WHO stated that simplified approaches such as foot length to identify preterm babies, were required for early identification and management of such babies [8]. Foot-length is measured from the heel to the tip of the big toe using a hard transparent ruler [6]. The landmarks are easy to identify and do not require special skills. Furthermore, the foot is easily accessible, and its measurement is quick and efficient even in very ill neonates, such as those nursed in the incubator, without exposing them to the risk of hypothermia [6]. In addition, it is not influenced by subcutaneous fat or sex [6]. However, variations across nations and ethnic groups do occur [6]. This study intends to determine the relationship between foot-length and gestational age. This will aid in the detection of premature neonates who may either benefit from early and simple lifesaving interventions or require referral for more specialized care.

Aim

The aim of this study was to establish a correlation between foot-length and gestational age

Method

The subjects were newborn babies: term and preterm whose weights were appropriate for GA delivered in ESUTH or admitted into the Special Care Baby Unit (SCBU) of ESUTH and who met the criteria for recruitment. Preterm and term babies who were delivered in ESUTH or were referred to ESUTH from other hospitals and babies who were within 96 hours of age were included in the study. Babies with congenital anomalies of the foot, neuromuscular disorders, congenital anomalies of the chest or skeletal abnormalities and babies with disorders that distorted respiratory rhythm and congenital skeletal abnormalities were excluded. The Lubchenco growth chart was then used to determine appropriateness for GA and babies who were SGA or LGA were similarly excluded. Babies with suspected chromosomal abnormalities and cardiovascular system disorders and babies with suspected intra uterine infections (Toxoplasmosis, Rubella, Cytomegalovirus and Syphilis) were also excluded from the study. Ethical approval was obtained from Enugu State University Health Research Ethics Committee, Enugu. Written informed consent was obtained from parent after due explanation of the study using the parent's desired language. Every step in the study was explained to the parents and they were assured that no adverse effects were expected. Only babies whose parents gave consent were recruited into the study. Gestational age was noted from the obstetric admission notes as calculated by LMP (GALMP) and/or early antenatal ultrasound (GAUSS), however, the NBS was used as the standard for gestational age. GANBS was used wherever a discrepancy existed with GALMP. Based on the gestational age, the babies were grouped as preterm and term.

Foot length measurements were from the heel to the tip of the big toe using a hard transparent plastic ruler. The foot was placed in a lateral position while the ankle was held, and a finger placed at the foot dorsum to avoid eliciting the grasp reflex which would shorten the measurement [9]. Care was taken to ensure that no pressure was exerted on the soft tissue. Both feet were measured. Measurements were performed by the researcher only to ensure a consistent measurement technique. Intra observer error was minimized by taking three measurements and then documenting the mean.

Data collated was coded, entered, and analyzed using International Business Machine Statistical Package for Social Sciences (IBM-SPSSversion 22 Chicago). Descriptive statistics such as frequency and percentages were used to summarize categorical variables (such as sex), while median and interquartile range were used to describe foot length because of non-normality of the data. Comparison of the foot length between term and preterm babies was done using Mann-Whitney U-test due to non-normality of data. The association between foot length, birth weight and gestational age (categorized into extreme preterm, very preterm, moderate-late preterm and term) was analysed using Kruskal-Wallis's test. Post-Hoc pairwise comparison was used to identify

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the areas of significant relationship between the categories of GA. Receiver Operating Characteristics (ROC) Curve was used to assess foot length as a marker of gestational maturity. All tests of significance were two-tailed at 95% confidence interval. A p-value score of < 0.05 is considered significant. Results were presented as prose, tables, and figures as appropriate.

Results

This study was conducted over a six (6) month period, from February to July 2020, with two hundred and thirty- five (235) participants enrolled. Three hundred and twenty- five (325) mothers were approached during the study period, thirty- two (32) refused consent while two hundred and ninety- three (293) gave consent. Twenty-seven (27) of the babies were either SGA or LGA, 28 were more than 96 hours at the time of measurements and three had congenital malformations. Eventually, 235 newborn babies who did not have any exclusion criteria were recruited for the study.

Socio-demographic characteristics of the study population

The dominant socio-economic class was class two (53.2%), with 3% and 0% in class four and five respectively. Mothers of 150 (63.8%) babies reside in urban areas while mothers of 85 (36.2%) babies reside in rural areas. Majority (99.1%) of the study participants were of the Igbo tribe, while 0.9% were of the Hausa/Fulani tribe.

Gestational age and sex distribution of the study population

Table 1: Socio-demographic characteristics of the study population.

	Frequency(n)	Percentage (%)
Socioeconomic class		
1	56	23.8
2	125	53.2
3	47	20
4	7	3
5	0	0
Domicile		
Urban	150	63.8
Rural	85	36.2
Tribe		
Igbo	233	99.1
Yoruba	0	0
Hausa/Fulani	2	0.9

The gestational ages ranged from 26-42 weeks (Table 1) with a mean (SD) of 37.0(3.4) weeks. Thirty- four (14.5%) were preterm while 201 were term. Amongst the 34 preterms, twenty-two (64.7%) were moderate too late. There were 121 males (51%) and 114 females (49%) giving a male to female ratio of 1.1:1. (Table 2).

Table 2: Gestational age and sex distribution of the study population.

	Frequency(N)	Percentage (%)
Gestational Age (Weeks)		
<28	3	1.3
28 to<32	9	3.8
32 to<37	22	9.4
>37 to 42	201	85.5
Total	235	100
Gender		
Males	121	51
Females	114	49
Total	235	100

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Foot length measurements of the study population

The foot length of the study population ranged from 5.10cm to 9.00cm with a median (IQR) foot length of 8.00cm (0.50). The median (IQR) foot length in the preterm and term subjects were 6.50cm (1.50) and 8.00cm (0.60) respectively (Table 3).

Table 3: Foot length measurements of the study population.

Foot length (cm)	Overall	Preterm	Term	U-stat	p-value
Median (IQR)	8.00 (0.50)	6.50(1.50)	8.00 (0.60)	472.5	<0.001
Min-max	5.10 – 9.00	5.10 – 7.8	7.00 – 9.00		

NB: IQR = Interquartile Range; Min = Minimum; Max = Maximum, cm = centimetres, U = Mann-Whitney U-test.

Foot length measurements amongst categories of GA

Among categories of gestational age, the median foot length increased with increasing GA. (Table Iva) shows that the median foot length increased significantly as the gestational age increased ($p < 0.001$). Post hoc pairwise comparison shows significant differences between the various categories of gestational age (Table IVb)

Relationship between foot length and gestational age

There is a positive correlation between foot length and gestational age ($R = 0.845$, $p < 0.001$).

(Figure 1) demonstrates this correlation. The coefficient of determination ($R2 = 0.714$) indicates that 71.4% of the variation in foot length can be attributed to gestational age. Hence the regression equation: GA = 12.35 + 3.37 x Foot length (cm), where 12.35 is a constant as derived by the regression model. 3.37 is the observed increment in weeks of gestational weeks for every increase of 1 cm in foot length. There is thus a linear association between foot length and gestational age (Figure 1).

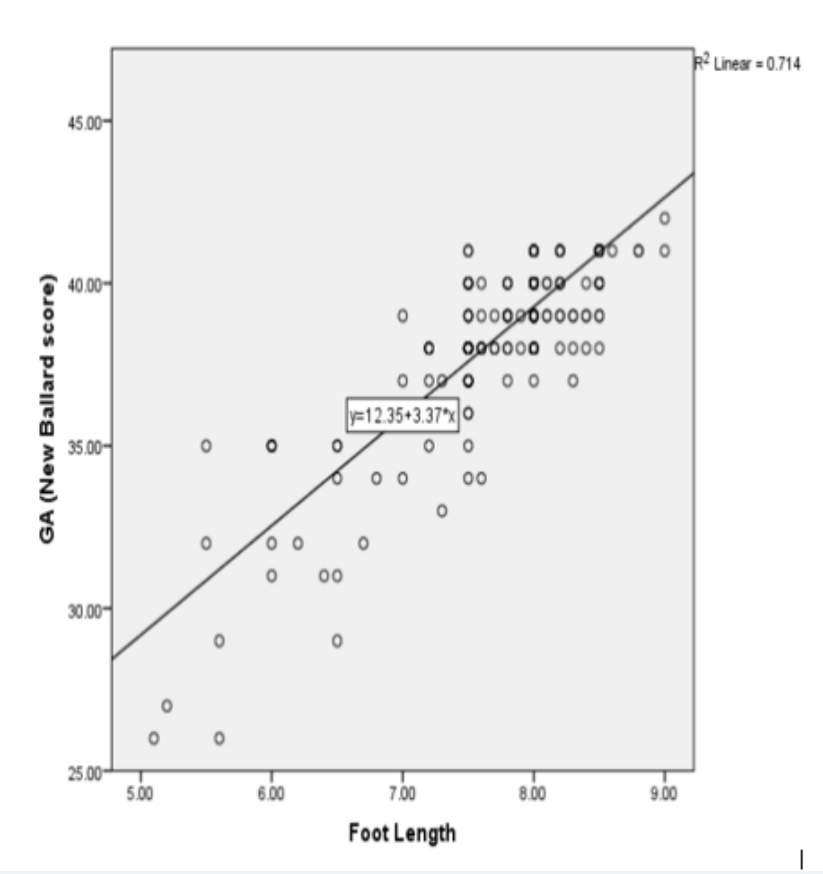

Figure 1: A scatter diagram showing the relationship between foot-length measurements and gestational age.

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Validity Estimates of Foot-Length as A Marker of Gestational Maturity

The Receiver Operating Characteristics Curve (Figure 2) showing plot of foot length vs. gestational age has an Area Under the Curve (AUC) of 0.931 and (95%C.I.) 0.878 - 0. 984.The best cut-off that maximizes (sensitivity+1-specificity) is 7.55cm (Figure 2). This is the optimal threshold that gives the maximum correct prediction of gestational maturity amongst both preterm and full-term infants. The ROC curve shows this maximum point (Figure 2). At this cut-off, the sensitivity is 74%, specificity is 94%, positive predictive value is 99% and negative predictive value is 38%. Foot length score equal to or greater than 7.55cm would indicate maturity in all neonates. In addition, a sensitivity of 74% indicates that, out of 201 term babies, 149 were correctly predicted (true positives) while a specificity of 94% classified correctly 32 out of 34 preterm babies (true negatives). A positive predictive value (PPV) of 99% shows that babies that were identified as term by the foot length measurements have 99% chance of really being term while a negative predictive value of 38% implies that babies that were identified as preterm by the foot-length have 38% chance of really being preterm. The false positive rate was 6% (6% of actual term newborns are classified as preterm by foot length measurement of newborns).

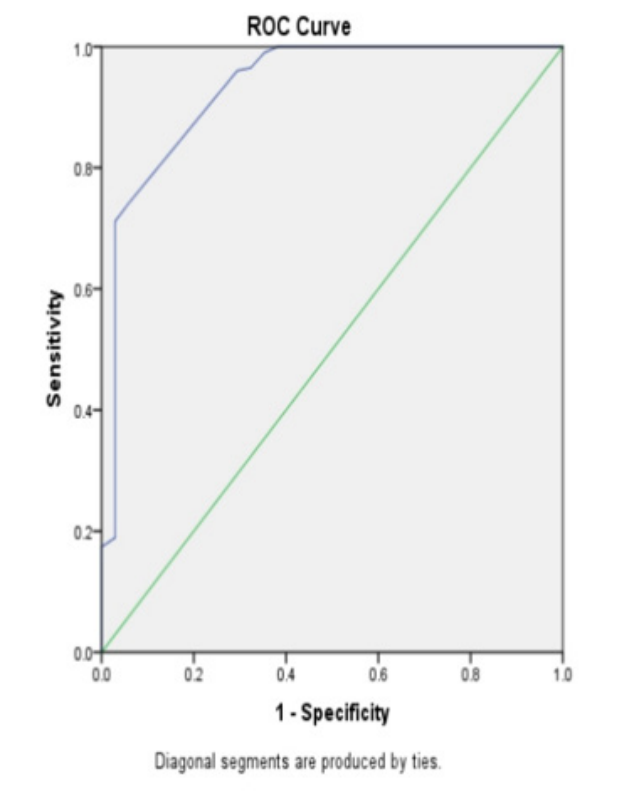

Figure 2: The ROC curve of foot-length for predicting prematurity in 235 newborn subjects.

Discussion

The findings in this study are comparable with those reported in previous studies [10,11]. For example, Ashish et al [12] and Mullany et al [7] reported mean foot length of 7.72cm and 7.92cm, respectively. The similarities in the values of foot length found in the index study with those of previous studies may be explained by some methodological factors. The methodological similarities in these studies include the use of transparent plastic tapes, common landmarks for measurement and the inclusion of preponderance of term neonates. However, despite the robust evidence in the literature suggesting similar values of foot length across studies in various continents [10,13], Wyk et al [9] found a much lower value (4.83 ± 3.05 cm) in a South African study. It is noteworthy that that study with contrary finding has a number of methodological differences with the present study. Firstly, whereas the present study used a transparent plastic measuring tape, a caliper was used in the South African study. Secondly, the landmark for the measurement of foot length varied in both studies. Furthermore, the variations in the values of foot length across studies in various continents may also be due to genetic and epigenetic factors [9,10]. In the present study, a statistically significant strong positive correlation was found between gestational age and foot length

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(r = 0.845, p < 0.001). This finding is in support of the robust evidence in the literature that have reported that foot length is an index of gestational maturity [9,14-18]. Several studies in Africa have reported the reliability of foot length as an index of gestational maturity [9,19,20]. For example, Wyk et al [9], who found a very strong positive correlation between foot length and GA (r=0.887) concluded that foot length measurement has high accuracy in determining gestational maturity and recommended it for use in localities with poor access to antenatal ultrasound. Similarly, Hadush et al [17] reported the usefulness of foot length as an index of gestational maturity in Ethiopian population. This finding is also strongly supported by other studies conducted in Bengaluru, and South Africa, where foot length and gestational age had a strong positive correlation [9,13]. However, a report in Vietnam showed a weaker but statistically significant correlation (r = 0.533; P < 0.001) [16]. Similarly, studies in Belgium, Indore, north India, and Nagpur observed a significant strong correlation between foot length and gestational age [14,21,22]. A linear association was obtained when FL was plotted against GA, which is comparatively similar to the linear curve obtained in other studies [14,21,22]. The increase in foot length with increasing gestational age observed in these studies is not unusual as it is widely known that anthropometric variables increase with gestational age as part of developmental process [23,24].

The present study found that at the cut-off of 7.55cm, foot length has a high specificity, sensitivity, and positive predictive value to identify gestational maturity. This shows that the performance of foot length as a marker of gestational maturity in this study is reliable. Although there is no standardized cutoff point for foot length in newborn babies, findings of this study is comparable to others done in Africa with foot length cut-point values ranging between 7.6-8cm [17,19,20]. The findings of this study also agree with the findings in some Asian studies which had foot length cutoffs ranging between 7.1-8.0 cm [11,12,16]. A study conducted in Ethiopia [25] found that a foot length ≤7.35 cm was 98.5% sensitive and 96.3% specific in identifying premature (<37 weeks) newborns which is comparable with the cutoff point found in the present study. In the context of this study, a high sensitivity and specificity suggests that foot length, at the cut-off point, will identify most of the mature babies (true positives) and most of the preterm babies (true negatives). The high PPV also adds to the performance of foot length in determining gestational maturity as the probability of those identified to be term being term is very high (Figure 3).

Figure 3: Foot length measurement in a sick preterm baby in the incubator.

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In addition, the diagnostic performance of foot length measurement was very strong in this current study, with AUC of 0.931. This is comparable to the 0.95 and 0.99 reported in previous studies in Uganda [20] and Ethiopia [25], respectively. This finding is higher than that of other studies conducted in, Nepal [9], Surakarta [11] and Vietnam [16] with AUC of, 0.683, 0.868 and 0.88 respectively. This may be due to the relatively higher sample size of the index study. In addition to smaller sample size, the study in Vietnam used a different instrument than this study (a Verniers calliper's) [16].

Table 4: Foot length measurements amongst categories of gestational age.

Gestational Age (weeks) N Median (IQR)		Foot length (cm)		
		H-test	p-value	
			17.23	<0.001
< 28	3	5.20 (0.00)		
28 to <32	9	6.20 (0.70)		
32 -to<37	22	7.50 (1.00)		
≥ 37 to 42	201	8.00 (0.57)		
H-test = Kruskal- Wallis test				
Gestational age weeks	28 to < 32	32 to < 37	≥ 37 to 42	
< 28	0.02	< 0.001	< 0.001	
28 to < 32		< 0.001	< 0.001	
32 to < 37			< 0.001	
Post hoc pairwise comparison of median foot length across gestational age groups.				

Table 5: Validity estimates of foot-length as a marker of gestational maturity.

	Term(n=201)		Preterm(n=34)					
Foot								
length	TP	FN	FP	TN	Sens	Spec	1-Spec	PPV %	NPV%
7.1	201	0	12	22	0.99	0.647	0.353	94	99
7.25	194	7	11	23	0.965	0.676	0.324	95	77
7.4	193	8	10	24	0.96	0.706	0.294	95	75
7.55	149	52	2	32	0.741	0.941	0.059	99	38
7.65	143	58	1	33	0.711	0.971	0.029	99	36
7.75	140	61	1	33	0.697	0.971	0.029	99	35
7.85	129	72	1	33	0.642	0.971	0.029	99	31

TP = true positive, FP = false positive, TN= True negative FN = false negative, PPV = positive predictive, NPV= negative predictive value, Sens = Sensitivity, Spec = Specificity.

Conclusion

In the setting of the present study, a foot length cutoff score of 7.55cm was the most specific and sensitive in predicting maturity among the study participants. Foot length correlated strongly and positively with gestational age (r= 0.845). Foot length was a highly sensitive tool for assessment of gestational maturity.

Recommendations

The recommendations, based on the findings of this study are as follows:

i. Foot length measurements may be adopted to be part of routine examination of newborn babies.

ii. The use of foot length measurements may be promoted for use in the detection of preterm babies especially in the rural settings.

Limitations

Gold standard for GA determination, early trimester ultrasound was not available to be used in this study.

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Competing Interests

The authors have declared that no competing interests exist.

Author's Contributions

Principal researcher, Dr Nzeduba designed the work, collected the data, and wrote up the article. Dr Nduka was a resident in newborn who helped with data collection. Drs Onyia and Agu assisted in writing the initial proposal for the work and helped with data analysis. Drs Asinobi, and Ekwochi reviewed the work. Profs Ikefuna and Ibeh supervised the work, data collection and write up.

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