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Kuponiyi Opeyemi Temitola
Ogunlesi Tinuade Adetutu
Dedeke Olabisi Florence

Relationship between postnatal foot length and selected anthropometric parameters in the estimation of gestational age among Nigerian neonates

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Ogunlesi Tinuade Adetutu (✉)
Department of Paediatrics,
Olabisi Onabanjo University,
Sagamu, Nigeria
P. O. Box 652, Sagamu-121001NG,
Nigeria
Email:
tinuade.ogunlesi@oouagoiwoye.edu.ng

Kuponiyi Opeyemi Temitola
Department of Paediatrics,
Olabisi Onabanjo University
Teaching Hospital, Sagamu,
Nigeria.

Dedeke Olabisi Florence
Department of Paediatrics,
Federal Medical Centre
Idi-Aba Abeokuta

Abstract: *Background:* Anthropometric parameters such as body weight, body length, occipitofrontal circumference and foot length are known to increase with gestational age. The estimated gestational age (EGA) is the approximate duration of pregnancy to the nearest two weeks at the point of birth.
Objective: To determine if there is a relationship between postnatal foot length and anthropometric parameters such as body weight, body length and occipito-frontal circumference in the estimation of gestational age among Nigerian neonates.
Methods: At the Olabisi Onabanjo University Teaching Hospital, Sagamu, Nigeria, a cross-sectional study was carried out among 260 neonates with EGA 30- 42 weeks within the first 48 hours of life between December 2017 and December 2019. Postnatal foot lengths were measured with Vernier digital caliper while body weight, body length and occipitofrontal circumference (OFC) were also measured using standard procedures.
Results: The postnatal foot length, body weight, body length and occipitofrontal circumference showed steady rise with increasing estimated gestational age. The boy weight ranged from 1.19± 0.14kg at 30 weeks to 3.41±0.44 at 42 weeks. The range of body length was 37.78±2.58cm at 30weeks to 50.60±1.67cm at 42 weeks. The occipitofrontal circumference also ranged from 26.65±1.47cmat 30 weeks to 35.40±1.63cm at 42 weeks. The foot length had strong correlation with the body weight (r = 0.892), body length (r = 0.754) and OFC (r = 0.801) in the preterm neonates. In the term neonates, the foot length had moderate correlations with each of the three parameters (r = 0.632, r = 0.473and r = 0.496).
Conclusion: Postnatal foot length had the highest correlation with body weight among preterm and term neonates hence, it will be a useful proxy for birth weight in the estimation of gestational age among Nigerian neonates.

Keywords: Anthropometry, birth weight, body length, foot length, head circumference.

Introduction

Anthropometric measurements at birth are reflective of intra-uterine growth and development and have the propensity to reliably predict the gestational age of the neonate. These parameters include body weight, body length, head circumference, mid-arm circumference, chest circumference, calf circumference, mid-thigh circumference, hand length, and foot length.
Body weight, a reflection of intra-uterine growth, is predictable by the gestational age and can be used to determine the intrauterine growth appropriateness of the neonate. Thus, it is readily used as the standard in anthropometry for estimating gestational age.
In Nigeria, some workers such as Olowe[1]and Mokuolu *et* al[2] have drawn charts depicting progressive increase in birth weight with gestational age, similar to the earlier observation of Lubchenco.[3] Oluwafemi *et al*[4] also reported an increase in the mean birth weight with increase in gestational age but with a drop at 42 weeks. These observations are supported by reports of moderate correlation between the birth weight and the gestational age in an Egyptian study,[5] and high correlation of the birth weight with the gestational age in Cameroun.[6]
The measurement of body length at birth can also be used as baseline for growth monitoring.[7] Oluwafemi *et*

al[4] also reported that the mean body length at birth increased with gestational age in term Nigerian neonates, except for a decrease at 41 weeks.

The postnatal foot length measurement was initially used for the estimation of gestational age when the body was mutilated and other fetal parts may be unavailable. Thus, the study of Manjunatha *et al*[8] revealed a linear relationship between foot length and gestational age (as determined by clinical examination) with a high correlation coefficient. Wong[9] studied live fetuses, using ultrasound scan and concluded that there was a positive strong correlation between the fetal foot length and the gestational age, similar to the findings of Manjunatha *et al.*[8] This is because the fetal foot length has a characteristic pattern of normal growth and has gradual increases in length relative to the length of the embryo.[10] Thus, by extension, the newborn foot length may also be used for gestational age estimation. It is attractive to find out any relationship between postnatal foot length and the usual anthropometric parameters such as weight, length, and occipitofrontal circumference so that one may possibly be deployed as a proxy for the other in the estimation of gestational age.[11]

At the lower tiers of healthcare where these neonates usually make their first presentations, expertise for appropriate designation of gestational age is lacking. Hence, gestational age- related risks are not assessed and optimal care is compromised with delayed or no referral to a higher-tier facility for adequate management. Therefore, a simple method requiring simple training, using simple tools for gestational age estimation which can be applied at all healthcare tiers is desirable for early institution of appropriate care.

If a relationship is established between the postnatal foot length (FL) (this is the measured distance between the most distal part of the heel and tip of the second toe on the ventral surface) and EGA, the management of ill neonates can be more rapidly instituted as clinical methods of EGA determination are time consuming and require greater skill compared to postnatal FL measurements.

Therefore, the objective of the study was to determine if there is a relationship between postnatal foot length and body weight, body length and occipito-frontal circumference in the estimation of gestational age among Nigerian neonates.

Materials and Methods

The hospital-based, cross sectional survey was carried out between December 2017 and December 2019 among singleton neonates aged 0-48 hours at the Olabisi Onabanjo University Teaching Hospital, Sagamu, southwest Nigeria. Only neonates of gestational age of 30 weeks to 42 weeks, determined from the maternal last menstrual period and corroborated with the New Ballard Scoring system, were included in the study. Excluded from the study were babies with Neonates with obvious gross congenital malformations and those with lower limbs deformities (including but not limited to talipes equinovarus, talipes calcaneovalgus and arthrogryposis.

Sample size

Using the formula for determining a population mean with precision:[12]

N = $Z\alpha 2\sigma 2/Ɛ2$ where:

N = Minimum sample size

Zα = Standard normal co-efficient = 1.96 at 95% Confidence Interval

SD(σ) = Standard deviation obtained from a previous study [13]

Ɛ = Margin of error (5%) above the mean obtained from a reference study [13]

The adopted minimum sample size was 20 for each gestational age, making a total of 260.

Anthropometric Measurements

The anthropometric measurements (body weight, body length and OFC) were determined/ measured within 48 hours of life. The body weight was measured by placing the naked neonate in the supine position in the center of a digital weighing scale (Seca® 384; Hamburg, Germany) calibrated in kilograms and the weight was read off to the nearest 0.1kg when the value on the scale stabilized.[14] Two body weight measurements per baby were taken and the average measurement was recorded.

The body length was measured by positioning the baby on the back in the center of the infantometer (Seca® 416; Hamburg, Germany) with the legs fully extended (by gentle pressure applied at the knees by a trained research assistant). The head was placed against the fixed headpiece of the equipment in the Frankfort Plane whilst the toes pointed upwards with the soles of the feet flat against the movable foot piece. The distance from the vertex (top of head) to the heel was read off to the nearest 0.1cm and recorded as the body length.[14] Two body length measurements per baby were taken and the average measurement was recorded.

A flexible but non-stretchable measuring tape calibrated in centimeters was used to measure the OFC to the nearest 0.1cm as the maximum diameter through the supraorbital ridge to the occiput.[15] Two measurements were also taken with the average measurement recorded.

Measurement of the postnatal foot length

The foot length (in millimeters) of each neonate was measured on the sole of both feet, between the heel and the tip of the second toe of each foot with the ankle stabilized in position. The foot length was measured using the Vernier digital caliper fixated between the tip of the second toe and the pterion without exerting pressure. The length was displayed on the caliper to one decimal place. The length of each foot was measured and the average was adopted for each neonate.

Data analysis

Data analysis was done using the Statistical Package for Social Sciences (SPSS) software version 20.0. Continuous variables were described as mean and standard deviations while categorical data were reported as percentages. The Student's t-test and One- Way ANOVA test were used to compare means and standard deviations. The relationships between the postnatal foot length and EGA and anthropometric measurements were determined using Pearson correlation or linear regression tests. P values less than 0.05 defined statistical significance.

Ethical considerations

Ethical approval was obtained from the Health Research Ethics Committee of Olabisi Onabanjo University Teaching Hospital, Sagamu (approval number: OOUTH/HREC/111/2017). Written informed consent was also obtained from the caregivers of the babies studied."

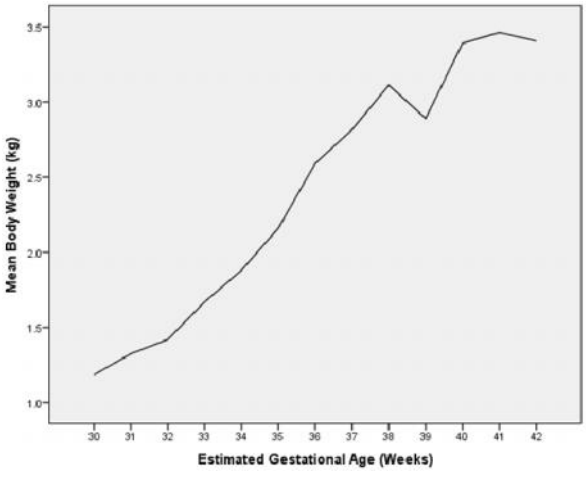
Results

Two hundred and sixty neonates, comprising 140 (53.8%) preterm neonates and 120 (46.2%) term were studied.

Anthropometry
Mean body weight

The mean body weight curve (Figure 1) showed a steady rise from early gestation (1.19kg), reached a peak at 38 weeks (3.11kg), and declined at the gestational age of 39 weeks (2.89kg), thereafter rising to another peak at 41 weeks (3.46kg), then declining at a more gradual gradient till 42 weeks.

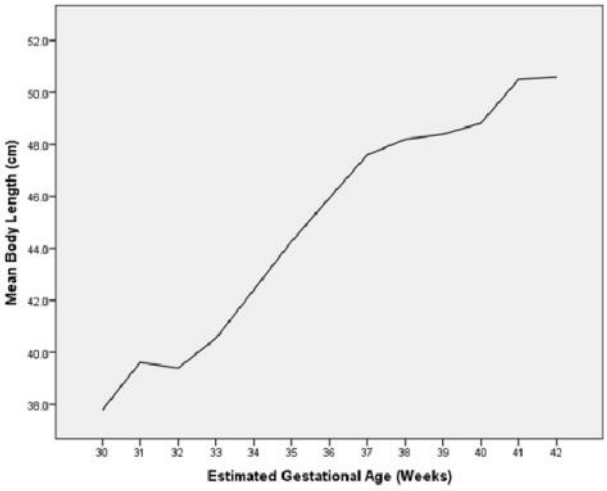
Fig 1: The trend in the mean body weight across the gestational ages



Mean body length

The mean body length curve showed a sigmoid-like curve (Figure 2) with an initial high gradient in which the body length increased with the increasing gestational age from 30 to 31 weeks (37.78cm-39.62cm), a plateau for another one week, then a sharp rise till 37 weeks (47.6cm), followed by a gradual rise till the 42nd week of gestation (50.6cm).

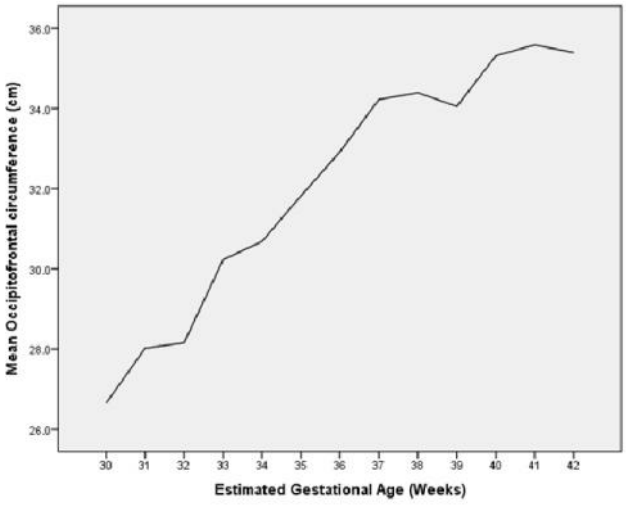
Fig 2: The trend of the mean body length across the gestational ages



Mean occipitofrontal circumference (OFC)

Figure3 shows a sharp rising slope from 30 weeks gestation (26.65cm) to the 37thweek (34.23cm) with a gradual slowing from the 37th week to the end of term. The peak OFC was reached at 41 weeks(35.59cm).

Fig 3: The trend of the mean occipitofrontal circumference across the gestational ages



Mean postnatal foot length (FLC) across gestational ages

The mean foot length increased with increasing gestational age as shown in Table 1. The mean foot length for

preterm neonates was 65.44 ± 6.92 mm while that of term neonates was 77.9 2± 4.24mm.

Table 3: Mean foot length across gestational ages

EGA	N	Mean (mm)	Standard Deviation
31	20	59.99	4.47
32	20	60.62	4.37
33	20	64.84	3.24
34	20	68.29	5.17
35	20	70.50	5.55
36	20	74.67	3.26
37	20	76.25	4.32
38	20	77.06	3.54
39	20	76.24	3.48
40	20	78.37	4.43
41	21	78.62	3.82
42	19	81.37	4.19
Total	260	71.21	8.59

Correlation of mean foot length and mean body weight, mean body length and mean OFC

As shown in Table 2, the foot length had strong correlation with the body weight, body length, and OFC in the preterm neonates. The strongest correlation of the foot length was with the body weight in both term and preterm neonates followed by the OFC. In the term neonates, the foot length had moderate correlations with each of the three parameters. The corresponding p values are as shown.

Table 2: Correlation of foot length with body weight, body length and occipitofrontal circumference in the term and preterm neonates

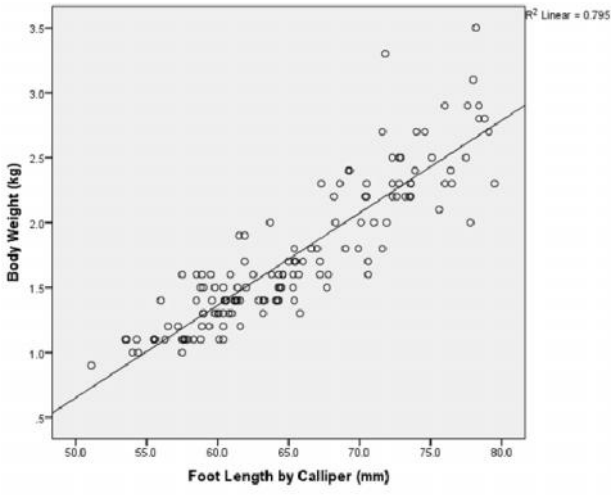
Maturity	Body weight			Body length			OFC		
	r	R^2	p	r	R^2	p	r	R^2	p
Preterm	0.892	0.795	0.000	0.754	0.569	0.000	0.801	0.640	0.000
Term	0.632	0.400	0.000	0.473	0.224	0.000	0.496	0.246	0.000

r = correlation coefficient, R^2 = Regression coefficient, p= level of significance

Scatter plot of body weight and foot length in preterm neonates

The scatter plot depicting the relationship between body weight and foot length in the preterm neonates is shown in Figure 4. The linear regression equation was generated as:
Weight = -2.90 + (0.07 x FL), R^2 = 0.795, p = 0.000.

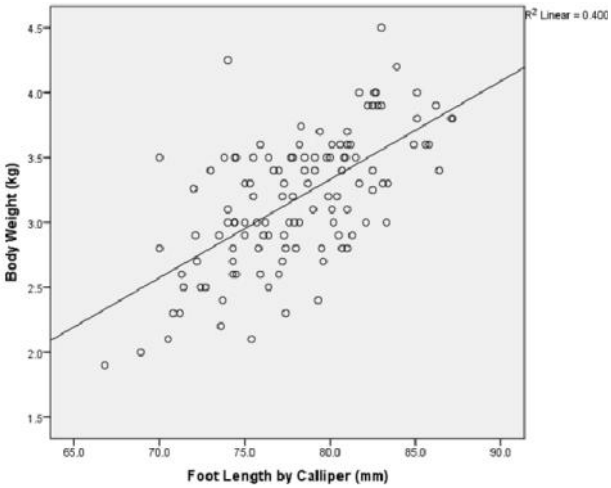
Fig 4: Scatter plot of body weight and foot length in the preterm neonates



Scatter plot of body weight and foot length in term neonates

The scatter plot depicting the relationship of the body weight with the foot length in the term neonates is shown in Figure 5. The linear regression equation generated was : Weight = -2.72 + (0.07 x FL), R^2 = 0.400, p =0.000.

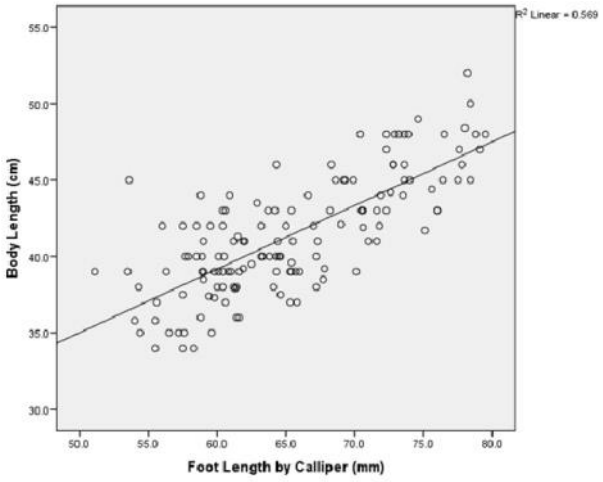
Fig 5: Scatter plot of body weight and foot length in term neonates



Scatter plot of body length and foot length in preterm neonates

The scatter plot depicting the relationship between the body length and the foot length is shown in Figure 6. The linear regression equation was: Length = 14.17 + (0.40 x FL), R^2 = 0.569, p= 0.000

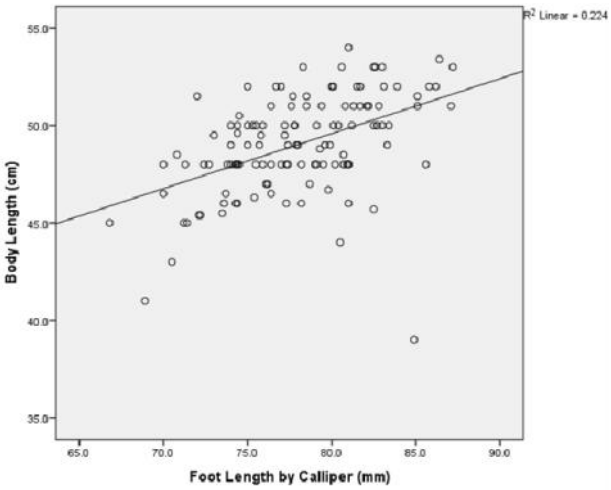
Fig 6: The scatter plot of the body length and foot length in preterm babies



Scatter plot of body length and foot length in term neonates

The scatter plot depicting the relationship between the body length and foot length in term neonates is shown in Figure 7. The linear regression equation generated was thus: Length = 27.01 + (0.28 x FL), R2 = 0.224, p = 0.000.

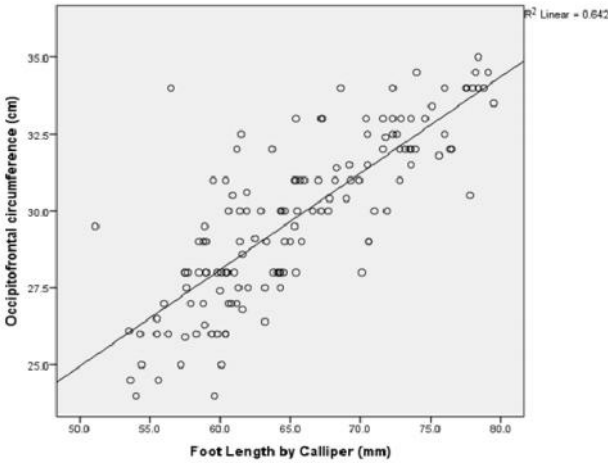
Fig 7: Scatter plot of body length and the foot length in the term neonates



Scatter plot of occipitofrontal circumference and foot length in preterm neonates

The scatter plot depicting the relationship between occipitofrontal circumference and the foot length in preterm neonates is as shown in Figure 8. The linear regression equation was thus: OFC = 9.27 + (0.31 x FL), R^2 = 0.642, p = 0.000.

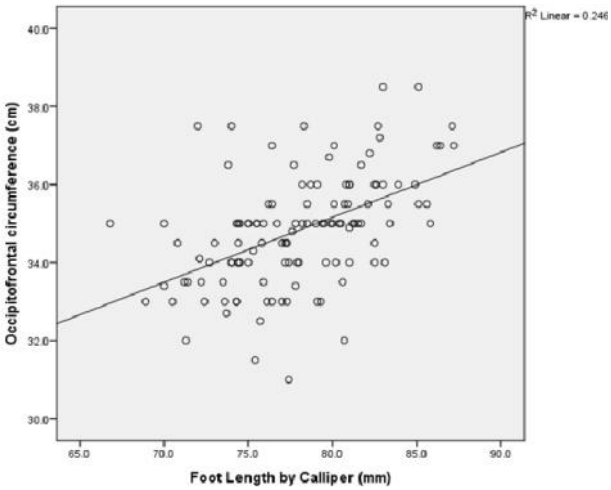
Fig 8: Scatter plot of occipitofrontal circumference and foot length in preterm neonates



Scatter plot of occipitofrontal circumference and foot length in term neonates

The scatter plot depicting the relationship between the occipitofrontal circumference and the foot length in term neonates is as shown in Figure 9. The linear regression equation generated was: OFC = 21.82 + (0.16 x FL) R^2 = 0.246, p =0.000.

Fig 9: Scatterplot of occipitofrontal circumference and foot length in term neonates



Discussion

This study was carried out to investigate the postnatal foot length as possible anthropometry proxy for gestational age estimation. In this study, FL had a positive, strong correlation with the body weight in the preterm neonates but moderate correlation in the term neonates. This observation may suggest that unlike somatic growth in general, the relationship between body weight and FL becomes less perfect as the foetus approaches term. In normal somatic growth of the fetus, comparative growth of body parts and organs result in an overall

increase in body mass (weight). Also, rapid weight increase is noted in the first and second trimesters with reduction in the rate of weight gain towards the term period as placental sufficiency wanes. This may therefore explain the moderate correlation with the FL in the term infants. The FL, noted to have the least likelihood of growth disruption with characteristic somatic growth pattern may therefore be representative of the summative mass in the fetal growth as reflected in the study.[10] Given the effect of maternal illnesses, particularly the chronic ones, on foetal somatic growth, it will be interesting to find out if maternal illnesses in pregnancy has any effect on FL. Similar moderate and strong correlations between the FL and body weight across the gestational ages as observed in this study were as earlier reported by Akwukwu et al[16] and Modibbo et al[17] in different parts of Nigeria. Similar findings were also reported by Van et al[13] in South Africa and Hadush et al[18] in Ethiopia. Srinivasa et al[19] and Amar et al[20] also documented similar findings in India. Therefore, the FL can be used as a proxy for the birth weight, particularly in preterm infants in circumstances of unavailability of weighing scale such as in lower tiers of health care delivery or in the community as a follow up of babies born outside the health facility. From its relativity to the birth weight, the postnatal foot length has been used by some researchers to identify and stratify low birth weight and premature neonates in Tanzania,[21] Nepal,[22] India[23] and Nigeria[24] with different foot length cut –off points but stratification into risk-groups is not included in the scope of this study.

There was a strong positive correlation of the FL with the body length in the preterm neonates but a moderate correlation in the term neonates resulting from a rapid length increase in earlier trimesters which slows down towards the term period. The foot length is an extension of the body length and grows relative to the body length but at a much less rapid rate.[10] Strong positive correlation between the FL and body length was reported across the gestational ages by Srinivasa et al[19] in India and Van Wyk et al[13] in South Africa. The relationship between the postnatal FL and body length observed in the present study could be translated to clinical use for gestational age estimation, especially in preterm neonates, in places where the appropriate equipment for body length measurement is unavailable.

The strong-to- moderate positive correlation of the OFC with the postnatal FL in the study is in tandem with the increase in fetal somatic growth as gestational age increases. Strong correlation between the FL and OFC signified the rapid head size development in the preterm period which slowed with little or no variations in the third trimester with resultant moderate correlation. Statistically significant positive correlations were reported in South Africa[13] and India[19] with high degrees of correlation in both studies.

The FL had a statistically significant strong positive correlation with the three anthropometric parameters in the preterm neonates and moderate positive correlations in the term neonates. The body weight had the strongest positive correlation with the postnatal FL, followed by the OFC and least with the body length in the present study. This may be because the body weight represents the total summation of tissue mass irrespective of aberrations in growth of individual bodily parts. Also, the OFC has been reported to have the least growth variation especially in the last trimester hence its preference for estimation of gestational age through the ultrasound method in late pregnancy.[25] Less variation in prenatal head growth may explain the better correlation with the postnatal FL compared to the body length. A similar trend was reported by Srinivasa et al,[19] unlike the trend in the VanWyk et al's[13] study where the least correlation of the FL was with the OFC as the latter study had a comparably smaller sample size to explore the relativity of the anthropometric variables.

The FL positively correlated best with the body weight in African and Asian studies as also found in this study. Therefore, it may be regarded as a good proxy for the birth weight in the estimation of gestational age.[13,26]

In conclusion, the postnatal foot length had the highest positive correlation with the body weight, followed by the OFC while the least correlation was with the body length in the preterm neonates. In the term neonates, the postnatal foot length had positive moderate correlation with the body weight, followed by the OFC and least with the body length. This study recommends that the postnatal foot length had the highest correlation with the birth weight hence it may be utilized as an alternative parameter for EGA assessment in the health care facilities in Nigeria.

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Authors' Contributions

KOT and OTA conceived and designed the study. KOT did the literature review. OTA analysed and interpreted the data. KOT and OTA drafted the manuscript and revised it for sound intellectual contents. All the authors approved the final version of the manuscript.

Conflict of Interest: None

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