INTRODUCTION

Prematurity is major neonatal morbidity that contributes significantly to under-five mortality.[1] Globally, about 15 million babies are born too soon every year, and over 60% of these preterm births occur in Sub-Saharan Africa and South Asia.[2] According to a recent analysis, 773,600 preterm births occur annually in Nigeria.[3] Birth weight is a potent predictor of their outcome, with worse prognosis in the lower birth weight categories.[4]

The relative immaturity of the organ systems in preterm babies greatly influences their survival. This increases the incidence of neonatal infections, perinatal asphyxia, and other complications among preterm babies especially the very low birth weight (VLBW) and extremely LBW (ELBW) categories.[4,5]

Beyond the neonatal period, the adequate growth of preterm infants continues to reflect and influence their overall health status. This is because prematurity and fetal malnutrition predispose to childhood undernutrition, infections, and other morbidities.[6] Underwood et al.[7]

Background: Optimal growth of preterm infants reflects their overall health status; however, indigenous growth charts are rarely available to monitor them adequately in infancy. Objectives: The aim of this study was to describe growth patterns of preterm infants and to generate percentile charts as well as relevant predictive equations for expected weight-for-age in their various birth weight categories. Materials and Methods: This was a prospective, analytic study. Anthropometric measurements of eligible consecutive preterm babies were monitored biweekly/monthly in infancy. Temporal changes in body weights and occipitofrontal circumferences (OFCs) were presented graphically. The Pearson’s correlation coefficient was done to derive predictive equations. LMS chartmaker light version 2.54 (Medical Research Council, UK) generated percentile charts. $P < 0.05$ was considered statistically significant. Results: A total of 154 preterm infants were recruited during the study period, with a male-to-female ratio of 1:1.5. Their mean gestational age (GA) was 31.3 ± 2.4 weeks, and mean birth weight was 1510.8 ± 347.5 g. Average daily weight gains were 9.4, 17.4, and 20.0 for extremely low birth weight (ELBW), very LBW (VLBW), and LBW, respectively, in the 1st month ($F = 1.733, P = 0.183$). The peak weight gain period occurred at the 4th month for ELBW (28.3 g/day), 5th month for VLBW (38.3 g/day), and 7th month for LBW (38.3 g/day). There was a strong positive correlation of their body weight with their postnatal age ($y = 505.6x + 1511.5; R^2 = 0.92$) as well as OFC with age ($y = 1.33x + 29.94; R^2 = 0.94$). Growth charts for weights and OFCs were generated showing 5th, 50th, and 95th percentiles.

Conclusion: The preterm infants gained weight with increasing postnatal age following an initial weight loss in the early neonatal period. Their relative growth velocities were similar in all birth weight categories.

Keywords: Growth, occipitofrontal circumference, preterm infants, weight

ABSTRACT

Background: Optimal growth of preterm infants reflects their overall health status; however, indigenous growth charts are rarely available to monitor them adequately in infancy. Objectives: The aim of this study was to describe growth patterns of preterm infants and to generate percentile charts as well as relevant predictive equations for expected weight-for-age in their various birth weight categories. Materials and Methods: This was a prospective, analytic study. Anthropometric measurements of eligible consecutive preterm babies were monitored biweekly/monthly in infancy. Temporal changes in body weights and occipitofrontal circumferences (OFCs) were presented graphically. The Pearson’s correlation coefficient was done to derive predictive equations. LMS chartmaker light version 2.54 (Medical Research Council, UK) generated percentile charts. $P < 0.05$ was considered statistically significant. Results: A total of 154 preterm infants were recruited during the study period, with a male-to-female ratio of 1:1.5. Their mean gestational age (GA) was 31.3 ± 2.4 weeks, and mean birth weight was 1510.8 ± 347.5 g. Average daily weight gains were 9.4, 17.4, and 20.0 for extremely low birth weight (ELBW), very LBW (VLBW), and LBW, respectively, in the 1st month ($F = 1.733, P = 0.183$). The peak weight gain period occurred at the 4th month for ELBW (28.3 g/day), 5th month for VLBW (38.3 g/day), and 7th month for LBW (38.3 g/day). There was a strong positive correlation of their body weight with their postnatal age ($y = 505.6x + 1511.5; R^2 = 0.92$) as well as OFC with age ($y = 1.33x + 29.94; R^2 = 0.94$). Growth charts for weights and OFCs were generated showing 5th, 50th, and 95th percentiles.

Conclusion: The preterm infants gained weight with increasing postnatal age following an initial weight loss in the early neonatal period. Their relative growth velocities were similar in all birth weight categories.

Keywords: Growth, occipitofrontal circumference, preterm infants, weight

INTRODUCTION

Prematurity is major neonatal morbidity that contributes significantly to under-five mortality.[1] Globally, about 15 million babies are born too soon every year, and over 60% of these preterm births occur in Sub-Saharan Africa and South Asia.[2] According to a recent analysis, 773,600 preterm births occur annually in Nigeria.[3] Birth weight is a potent predictor of their outcome, with worse prognosis in the lower birth weight categories.[4] The relative immaturity of the organ systems in preterm babies greatly influences their survival. This increases the incidence of neonatal infections, perinatal asphyxia, and other complications among preterm babies especially the very low birth weight (VLBW) and extremely LBW (ELBW) categories.[4,5]

Beyond the neonatal period, the adequate growth of preterm infants continues to reflect and influence their overall health status. This is because prematurity and fetal malnutrition predispose to childhood undernutrition, infections, and other morbidities.[6] Underwood et al.[7]
and Lain et al.\[8]\) found that readmission rates were much higher among preterm infants, especially ELBW infants, due to frequent respiratory, gastrointestinal, and infectious disorders. Preterm infants have over the 2-fold risk of growth faltering in early childhood, with possible impacts on their neurodevelopment.\[10]\) Hence, accurate growth monitoring of preterm infants is desirable.

Growth in infancy is influenced by intrauterine environment, nutrition, and genetic constitutions. Hence, due to the interplay of nature and nurture on physical growth, reference norms may differ among populations.\[10]\) The Fenton growth chart for preterm infants was derived in developed setting.\[11]\) Huang et al.\[15]\) found that growth curves of breastfed infants in China were significantly different from those based on the World Health Organization (WHO) standards.\[12]\) Similarly, Louis et al.\[18]\) reported that fetal growth differed significantly by race/ethnicity in the NICHD fetal growth studies.\[13]\) The foregoing clearly suggests that genetic constitutions influence growth. Hence, a recent systematic review concluded that the use of a single international standard for human growth in all ethnic groups is suboptimal.\[14]\) In addition, the WHO growth charts were derived only from term infants in affluent homes,\[15]\) requiring corrections for gestational age (GA) in preterm infants. Furthermore, feeding preterm infants to achieve postnatal catch-up growth may be detrimental to their future health due to metabolic programming.\[16]\)

Consequently, the description of growth pattern of preterm infants is still an unmet need in several populations.\[14]\) In Cameroon, Mah et al.\[17]\) found that the mean daily weight gain of VLBW preterm infants was 17.35 g/kg/day while their occipitofrontal circumference (OFC) increased at a rate of 2.5 cm/month for males and 2 cm/month for females. There is a dearth of data on growth patterns of preterm infants in Nigeria. About a decade ago, Njokanna et al.\[18]\) reported that after an initial weight loss, growth rates of preterm LBW Nigerian babies were 188–238 g/week (weight), 0.86–0.96 cm/week (length), and 0.48–0.50 cm/week (OFC) in early infancy.\[19]\) These rates were slower than values reported among Caucasian infants.\[18]\) There is no prior research in our practice setting on preterm growth. Therefore, this study aims to describe the growth pattern of preterm babies in infancy. We also generated percentile charts for each gender as well as relevant predictive equations for expected weight/OFC-for-age in the various birth weight categories.

### MATERIALS AND METHODS

#### Study setting and participants

The study was carried out at the Mother and Child Hospital (M and CH), Akure. It is a 100-bed, ultramodern public facility with Level II neonatal intensive care units (NICU) providing specialized free healthcare services to the state capital, allied communities, and neighboring states in Southwestern Nigeria. Akure is the state capital of Ondo State which has a total fertility rate of 5.\[19]\)

This prospective, analytic study was done from June 2011 to December 2013. Ethical approval for the study was obtained on 30th March 2012 from Mother and Child Hospital Akure Ethics committee (MCHA/REC/2012/03/no 03) The participants were all consecutive inborn preterm infants born during the study period. Exclusion criteria were orofacial malformations, major congenital anomalies, and smallness for GA.\[20]\) Preterm birth was defined as delivery before 37 completed weeks of gestation. When the date of the mother’s last regular menstrual period was uncertain; their GA was estimated using the Ballard maturational score.\[21]\) They were fed exclusively on breast milk. Trophic feeding was started 10–20 ml/kg/day and increased as tolerated. Nutritive feeding was gradually increased to 80–120 kcal/kg/day. ELBW and VLBW were fed through cup-and-spoon feeding; however, direct breastfeeding of LBW babies was often achieved during in-patient care. While on follow-up at the consultant outpatient clinic, they were counseled on optimal infants and young child feeding as per standard practice.\[22]\)

#### Data collection

Data were collected on every participant on an Excel sheet listing variables in the following sections: demographic features, birth history, diagnosis, and anthropometry. Modes of delivery and their indications were documented. Their GA, gender, birth weight, and OFC were determined. The infants were weighed using an electronic Seca\® scale (Seca gmbh & co, Germany) with a sensitivity of 0.01 kg. Measurements started at birth. Daily weighing was done while on admission. They were followed up every 2 weeks in the 1st month after discharge, then monthly thereafter until the 12th month. Weights and OFCs were entered into the Excel sheet, and data were reviewed for completeness on every clinic visit.

#### Data analysis

Data were analyzed using SPSS version 20.0 statistical software for Windows (IBM, Armonk, N.Y., USA).
Categorized data were presented as percentages. Percentage weight loss following birth was computed as follows: (birth weight – nadir weight)/birth weight × 100%. Means of weight gain/loss (g/day) in various birth weight categories were compared using F-test. Relative weight gain velocity (g/kg/day) was obtained by dividing the mean weight gain by the mean weight (kg) in each birth weight category. Temporal changes in body weights and OFCs during the follow-up period were presented graphically. The Pearson’s correlation coefficient was done to derive predictive equations. LMS Chartmaker light version 2.54 (Medical Research Council, UK) was used to derive percentile charts for weights and OFCs. P < 0.05 was considered statistically significant.

RESULTS

Baseline features of the preterm infants
A total of 154 preterm infants were recruited during the study, with a male (61)-to-female (93) ratio of 1:1.5. Based on GA classification, 34 (22.1%) were late preterm (≥34 weeks), 33 (21.4%) were moderate preterm (≥32 weeks), 80 (51.9%) were very preterm (≥28 weeks), and 7 (4.6%) were extremely preterm (<28 weeks). Their mean GA was 31.3 ± 2.4 weeks; range 25 weeks–36 weeks. Their mean birth weight was 1510.8 ± 347.5 g (range = 700 g–2300 g). Eighty-two of them (53.2%) were LBW, 63 (40.9%) were VLBW, and 9 (5.8%) were extremely ELBW. Ninety-four (62.3%) of them were delivered by spontaneous vertex delivery, 53 (35.1%) by cesarean section, and the rest by forceps (1.3%) or breech extraction (1.3%). About a half (53.0%) of them were born into families in the upper socioeconomic class (SEC), 30.0% in the middle, and 17.0% in the lower SEC. The most common neonatal morbidity among them was jaundice (69.0%); one of them was an infant of rhesus-negative mother. In addition, 97 (62.9%) of the infants had presumed/probable sepsis; 21 (13.6%) had perinatal asphyxia, 19 (12.3%) hypoglycemia, 13 (8.4%) respiratory distress syndrome, and 8 (5.2%) had anemia. All these morbidities were appropriately treated in the affected infants. The overall case fatality rate of prematurity was 5.6% during the study period.

Body weight changes of the participants on follow-up
The preterm babies lost varied proportions of their body weight in the 1st week of life depending on their maturity. Their mean percentage weight losses were as follows: 13.1% for ELBW, 11.8% for VLBW, and 8.9% for LBW categories; there was no significant difference in the proportions of weight loss among the participants (P = 0.491). They gradually regained birth weight from the 2nd week. The overall trend of daily weight gain of the participants after discharge is shown in Figure 1.

Average daily weight gains were 9.4 g/day, 17.4 g/day, and 20.0 g/day for ELBW, VLBW, and LBW, respectively, in the 1st month (F = 1.733, P = 0.183), and their relative weight gain velocities were as follows: ELBW (11.1 g/kg/day), VLBW (13.8 g/kg/day), and LBW (11.2 g/kg/day). Seventy-four (90.2%) of the LBW infants and 39 (61.9%) of the VLBW regained their birth weights by the age of 2 weeks, but none of the ELBW regained birth weight at that age. The mean duration of admission was 7.1 days (1–49 days); an average of 25.5 days for ELBW, 11.4 days for VLBW, and 7.2 days for LBW infants. Their peak weight gain periods occurred at the 4th month for ELBW (28.3 g/day), 5th month for VLBW (38.3 g/day), and 7th month for LBW (38.3 g/day). At the 7th month, estimated 15.6% of the infants had defaulted while 53.2% stopped their follow-up at the 9th month. Their rates of weight gains were not significantly different throughout the study period (F = 0.245, P = 0.785).

Correlation of anthropometry with postnatal age
There is a strong positive correlation of all the participants’ body weight with their postnatal age [Figure 2; R² = 0.92]. Predictive equations for expected body weight in the various subcategories of preterm infants were derived as follows: ELBW (y = 500.15x + 123.03; R² = 0.90), VLBW (y = 523.17x + 1181.7; R² = 0.93), and LBW (y = 750.35x + 1006.8; R² = 0.98). Similarly, there was a gradual increase in their OFCs throughout infancy [Figure 3].

Growth charts for preterm infants
Growth charts for preterm infants comprising of weight-for-age percentiles and OFC-for-age...
percentiles were generated for each gender. The 5th, 50th, and 95th percentile lines are shown in Figures 4 and 5. Furthermore, see the supplementary file to this report [Figures 6-10].

**DISCUSSION**

This study describes the growth patterns of preterm newborns in infancy. The initial reduction in their body weights in the early neonatal period was mainly due to physiologic loss of body fluid in newborns, which may be more marked in preterm infants. The proportions of initial weight loss (8.5%–13.1%) found in this study were similar to ≤13.9% reported in 2008 by Njokanma et al. in Lagos and ≤13.3% by Anchieta et al. in Brazil among appropriate-for-GA preterm infants, with greater initial weight losses occurring in the lower birth weight categories in all the series. This is due to the increasing body water composition with increasing immaturity. Furthermore, the suboptimal absorptive capacity of their immature kidneys and their relatively large body surface area favors body water loss leading to the larger initial body weight loss noted in the lower birth weight categories. Less initial weight loss occurs in term infants as well as small-for-GA infants.

Many of the LBW and VLBW infants gradually attained and exceeded their birth weights by the end of the 2nd week consistent with earlier reports. The growth velocity of VLBW infants in this study is comparable to the value of 17.35 g/kg/day reported by Mah et al. in Cameroon. There was a predominant upward trend in the rate of daily weight gain until the age of 6 months among the participants reflecting their improving breast milk intake and gastrointestinal tract maturation. Following the peak weight gain velocity at 6 months [Figure 1], there was a gradual decline in their rate of weight gain until the 9th month before a steady rise continues until the end of infancy. The declining growth velocity after the age of 6 months coincides with the period of introduction of supplementary feeds that may be characterized with growth faltering in exclusively breastfeed infants especially when there are concurrent illnesses. Furthermore, some infants are picky in their eating habits, and this may further reduce their nutrient intake, compromising their growth.

The ELBW infants had an initial slightly lower rate of daily weights gain than the other preterm categories, perhaps due to their extreme immaturity and poor enteral feeding in the early neonatal period, as well as the presence of comorbidities. Again, there is a high rate of endogenous protein loss in preterm infants predisposing them to malnutrition in early infancy. Although enteral feeding with human milk is the optimal feed for newborns due to its caloric and immunologic constituents, their immaturity may hinder adequate oral intake. Consequently, the partial parenteral nutrition, especially amino acid infusion, may be beneficial in ELBW babies during the early neonatal period. However, advanced nutritional supports were not readily available in our center, and none of our participants received total parenteral nutrition.

There is a strong correlation of anthropometry with postnatal age among our participants, yielding highly
predictive equations for both expected weights and OFCs-for-age. These are useful in clinical monitoring of preterm infants in various birth weight categories following discharge from NICU. These may be more realistic growth targets for NICU graduates than values extrapolated from intrauterine fetal growth trends when the fetus had uninterrupted nutrient supplies.\cite{11,13} Furthermore, the OFC is an indirect measure of the constituents of the skull, especially optimal brain growth, which is paramount to neurodevelopment in infancy. Similarly, accurate OFC monitoring could facilitate early detection of pathological head enlargement, such as hydrocephalus, which is relatively common among preterm infants.\cite{30} This may enable prompt intervention to minimize neurocognitive impairment.

The growth charts generated from this study are useful in all preterm infants because the various birth weight categories were recruited. The WHO growth charts do not include preterm infants, necessitating routine correction for GA before use.\cite{16,22} The index charts can be used without such corrections especially in infants born at ≥31 weeks which is the mean GA of our participants, enhancing their user-friendliness. They reflect the typical growth pattern of NICU graduates in our setting which may differ from term infants’ trajectories until the 2nd year of life.\cite{22} This forestalls
rigorous pursuits of catch-up growth in early infancy which can be detrimental to the future health of preterm babies due to metabolic programming and associated morbidities.\textsuperscript{[16]}

Although infants’ lengths were not taken in this study, body weight and OFC are sensitive measures of physical growth.\textsuperscript{[13,24]} The strength of this study includes its prospective nature and the inclusion of preterm infants in all birth weight categories. Their respective predictive equations for expected weight/OFC can be used without corrections for GA. Furthermore, our participants were from all socioeconomic classes unlike the WHO growth charts that were derived from term infants in the upper wealth quintiles and may inadvertently classify others as undernourished.\textsuperscript{[14,15]} Nonetheless, a large multicenter study on growth and development of preterm infants is desirable in Nigeria.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig5.png}
\caption{Growth charts for female preterm infants: (a) Body weight and (b) occipitofrontal circumferences}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig6.png}
\caption{Daily weight gain trend of preterm infants on follow-up by birth weight categories. Their relative weight gain velocities were as follows: extremely low birth weight (11.1 g/kg/day), very low birth weight (13.8 g/kg/day), and low birth weight (11.2 g/kg/day)}
\end{figure}
CONCLUSION

Preterm infants gained weight with increasing postnatal age following an initial weight loss in the early neonatal period. The relative growth velocities (g/kg) were similar in all birth weight categories. Accurate anthropometric monitoring of preterm infants using indigenous tools is desirable.

Acknowledgments

The authors would like to thank the management and members of staff of the Mother and Child Hospital, Akure, Ondo State.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES


