Using Anthropometric measurements for Gestational Age Assessment in Sudanese Preterm Infants

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Research Article

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Abstract

Background:

South Asia, accounts for 60% of preterm births worldwide. To provide vital care and prevent complications that arise with preterm births, accurate determination of gestational age is important.

Methods:

We conducted a cross-sectional study at Maternity Hospital in Sudan, to evaluate the use of anthropometric measurements (head-circumference and crown-heel-length) for Gestational age assessment. Our sample included preterm babies over a period of six months. Neonatal anthropometry measurements, and Gestational age assessment was done within 48 hours of birth. Variables were summarized using descriptive statistics and the strength of association was determined through correlation analysis. Linear regression equations were derived to estimate gestational age using head circumference and crown heel length.

Introduction

Every year, a staggering 15 million babies are born prematurely, of which one million do not survive.(1)

Annually, 98% of global neonatal deaths take place in developing countries, where newborns are likely to die within the confines of their homes. (2) On evaluation of the UNICEF Progress Report of 2012, Sub-Saharan Africa was observed to have the highest risk of death in neonates within the first month of life. (3) Although the region has seen a considerable decline in its under-five mortality rate,(3) a substantial amount of progress yet awaits to achieve the sustainable development goal of 12 or fewer neonatal deaths per 1000 births.(4) In particular Sudan, a member of WHOs list of least developed countries (LDC), (5) experiences neonatal mortality of 41 per 1000 live births, compared to the highly contrasting 10 per 1000 live births in Europe.(6)

Among the various factors contributing to infant mortality within the first 5 years of life, preterm birth is a major contender.(1) Infants who survive against these odds, are afflicted with long-term adverse consequences. These ramifications may be attributable to a heightened susceptibility to infections, as well as complications that arise from impaired respiration, difficulty feeding, and poor body temperature regulation.(7) Evaluating neonatal gestational age (GA) at birth is essential in determining the wellbeing of the child and often plays a major role in choosing the intensity of care required. Accurately assessing the gestational age, however, often requires certain prenatal and postnatal indicators such as last menstrual period (LMP), neonatal data, and most importantly, the first-trimester ultrasound.(8–11) Owing to the scarcity of resources, less than 7% of women in sub-Saharan Africa acquire an ultrasound, which makes the aforementioned data difficult to obtain.(12, 13) As cost-effective and feasible alternatives, New Ballard Scores (NBS) and Parkin scores are now being put to use.(14) The NBS is primarily used to assess gestational age in most of the tertiary care neonatal units in Sudan. However, it relies on external and neurological features, which are frequently found to be impacted by birth trauma, asphyxia, and intrauterine factors.(15–17)

In this paper, we evaluate the use of anthropometric measurements, particularly neonatal head circumference (HC) and crown-heel length (CHL) to determine the gestational age of the neonate, and its efficacy in comparison to the NBS.

Methods And Material

Participants for our study were recruited using the convenience sampling model, from the Neonatal Intensive Care unit NICU department at the Omdurman Maternity Hospital, Sudan. Informed consent was taken from patient's parent/guardian before taking measurements and using them in our statistical analysis. The consent form is attached in the appendix.

Eligibility Criteria:

In our study, we included all preterm babies (25–37 weeks of gestation) admitted at the NICU from June 2019 to December 2019. Neonates who had congenital malformations, birth traumas, neural tube defects, or critical illnesses were excluded from our study.

Data Collection Tool And Procedure:

For all included neonates, gestational age (GA) was calculated within the first 48 hours, using the new Ballard scoring system as the gold standard. Neonatal Head Circumference (HC) and crown heel length (CHL) were also measured in the aforementioned time frame.

All anthropometric measurements were performed by one investigator with the neonate placed supine in the anatomic position. Measurements were made using a flexible, non-stretchable measuring tape to the nearest millimeter. HC of all participants was measured over the largest circumference of the head just above the ears and eyebrows, to the widest part of the back of the head. CHL was recorded from the top of the head to the heels. The infant was laid in the anatomic position with both legs extended and toes pointing upwards. The Fenton growth chart percentile for different genders was used to categorize neonatal anthropometry (HC and CHL) for GA.

Statistical analysis:

A sample size of 372 was calculated using the single population proportion formula assuming 40% of subjects have the factor of interest at 95% confidence interval. A margin of error of 5% was used.

For the data collected, all baseline characteristics and descriptive data were analyzed using Microsoft Office Excel to calculate the mean, median, minimum value, maximum value, standard deviation, and standard error of the mean. All statistical tests were conducted at the level of 1- sided alpha level of 0.05, while the beta value to reject the null hypothesis was set at < 0·20.

Correlation between the two anthropometric measures and GA was evaluated to determine the association between the two variables. For the predicted GA, simple and multivariate regression analysis was performed, and linear regression equations were derived to estimate GA using the parameters of HC and CHL.

A Pearson correlation coefficient r-value of > 0·7 was considered to have high collinearity. Moreover, standardized and unstandardized coefficients were quantified to detect the collinearity between the predictors. Finally, since confounding factors were difficult to eliminate at the level of study design, a multivariable regression model was used to control it at the level of statistical analysis.

Results

A total of 372 neonates met our study criteria and were included in our analysis. Of these 51·1% were male and 48·9 % were females. With regards to the mode of delivery, our population consisted of 187 neonates who were delivered vaginally (50·3%) and 185 (49·7 %) who were delivered via a cesarean section.

For included neonates the HC ranged from 22·0- 33·5 cm with a mean of 28·7 ± 2·5cm. On the other hand, neonatal CHL ranged from 31·5 - 50·0 cm with a mean of 41·6 ± 3·8 cm.

The bulk of our population 233 (62·6%) was classified as *very preterm* according to the WHO classification while 83 (22·3%) and 66 (17·7%) subjects were classified as *moderate to late preterm* and *extremely preterm* respectively. Similarly, majority of the population had appropriate crown heel length and head circumference according to their gestational age; 88·2% and 90·9% respectively. Other baseline characteristics of our study population are summarized in Table 1 below.

We observed a strong correlation between both measured anthropometric values and GA (calculated using the New Ballard Scoring System). The Pearson chi-square test for symmetric measure demonstrated a value of 0·02 (p<0·05); thereby proving the relationship between neonatal GA and anthropometry.

When assessing Neonatal HC, an increase from 22·5 ± 0·5 cm at 25 weeks to 30·5 ± 0·0 cm at 36 weeks was observed (Table 2). Moreover, a strong correlation was revealed between HC and GA by the Pearson Correlation analysis ($r = 0{\cdot}704$, $r^2 = 0{\cdot}494$, $p < 0{\cdot}05$). Similarly, neonatal CHL was also found to be steadily increasing with GA from 33·5 ± 0·0 cm at 25 weeks to 46·8 ± 3·3 cm at 36 weeks (Table 3). Using the aforementioned values, percentile tables for both HC and CHL were generated from 5^{th} to 95^{th} percentile (Supplemental Tables 1 and 2). The calculated Pearson's r value for the correlation was 0·810 (p<0·05) with CHL accounting for 65·5% of the variability in GA. Lastly, a Pearson correlation analysis of combined anthropometric measures with gestational age revealed the strongest correlation, with an r-value of 0·834

(r^2= 0·695, $p < 0·05$). Scatter plots of the correlations between HC-GA, CHL-GA and HC+CHL-GA are depicted in Figures 1, 2 and 3 respectively.

In addition to analyzing the correlation between anthropometric values with GA, simple and multiple linear regression analyses were also performed to derive equations for the calculation of GA using the above-mentioned anthropometric measures. The regression equations derived for the calculation of GA from HC and CHL were GA=0·504*(HC in cm) +16·3 and GA=0·478*(CHL in cm) + 10·936 respectively.

Since the correlation between HC+CHL with GA was observed to be the strongest, a multiple linear regression equation was derived to predict GA using the CHL as well as the HC: GA=0·197*(HC in cm) + 0·36 (CHL) + 9·9.

Discussion

Assessment of gestational age plays a pivotal role in determining the level of care required by a preterm neonate, its subsequent growth, development, and survival.(18) While methods utilized for gestational age assessment include ultrasound investigations,(19) LMP,(20) 21-item Dubowitz, (21) 12-item Ballard, (22, 23) the 6-item Capurro,(24) and the 6-item Eregie, (25) only the former two are considered to be the gold standard. However, owing to certain impediments, such as poverty and subsequent scarcity of resources, access to ultrasound investigations is hindered.(13) Moreover, maternal illiteracy—with the resultant lack of antenatal care and poor documentation of LMP—poses significant challenges in the determination of gestational age.(20) Consequently, the failure to detect preterm pregnancy results in delay in interventions that could prevent neonatal morbidity and mortality.(26)

The NBS system, which is the current standard for GA assessment in developing countries, has a physical and neurological criterion. Despite the accuracy of this assessment, certain limitations reduce its efficacy in low-middle income countries (LMICs). These include the requirement of pediatric-trained personnel, as well as variations in assessments conducted by different individuals. In contrast, anthropometric measurements collected by health workers are more reliable, since they are easier to perform and are free of observer bias.(27)

Among our principal findings, we observed a significant linear relationship between head circumference, CHL and GA. Within this analysis, the correlation of HC + CHL with GA was determined as the most significant. Additionally, our analysis guided the preparation of an equation to determine gestational age through anthropometric measurements of head circumference, crown-heel length, or a combination of both.(28)

Gestational Age And Anthropometric Values:

In our study, the mean head circumference at 25w, 26w, and 27w, was 22·5 ± 0·5cm 23·7 ± 1·8cm and 24·6 ± 1·1cm respectively, for both genders. These results demonstrated considerable similarity to a study conducted in the US, wherein, the mean percentile for head circumference at the aforementioned gestational ages, were 22·7cm, 23·6cm, 24·5cm and 23·2cm, 24·2 cm, 25·2cm respectively, for both males and females.(29) Our results for head circumference were also corroborated by a study conducted in Turkey, which demonstrated a mean head circumferences, very similar to our own; for neonates at 34w, 35w, 36w of gestation.(30) A study conducted by Das et al in India however, demonstrated the mean percentile of head circumferences to be 24·1cm, 24·6cm and 24·7cm at 28w, 29w and 30w. These results were found to be contrary to the mean percentile of our population (25·5cm 27·5cm 29·0cm).(27)

With regards to CHL, a multi-center cross-sectional study conducted across 248 hospitals in the US revealed measurements of mean percentile of head circumference and crown heel length that were like our study. The mean crown heel length at 25w, 26 w, and 27w in the aforementioned study were 32·3cm, 33·6cm, and 35·0cm for females and 32·9cm, 34·3cm, and 35·7cm for males respectively.(29) In our study, the mean crown heel length for 25w, 26w, and 27w were 33·5 ± 0·0cm, 33·6 ± 1·5cm,, and 35·5 ± 1·3cm for both genders.

These results were corroborated by the aforementioned study conducted in Turkey which, at 34w, 35w, 36w, reported a mean percentile for crown heel length of 44·9cm, 46·5cm, 47·8cm, and 45·5cm, 46·0cm, and 47·3cm for males and females respectively.(30) In our study, the mean CHL for the aforementioned GAs were 45·3 ± 1·6cm, 46 ± 0·0cm, and 46·8 ± 3·3cm respectively.

Similar to HC, Das et al reported a mean crown heel length which differed from the findings observed in our population (37·6 ± 2·5cm 39·3 ± 1·6cm, and 41·5 ± 2·2cm at 28w 29w and 30w respectively). (27)

The disparity observed between the percentiles in our study, in contrast to studies conducted across the world, could be attributed to varying economic backgrounds, differences in sample size, ethnicity and demographic profile.

Correlation Between Anthropometric Values And Ga

On analysis, our results corroborated the findings of a study conducted within a Western Indian population, which demonstrated a strong correlation between GA and HC (r = 0·977).(31) Similarly, Das et al demonstrated a strong correlation (r = 0·863) between HC and GA of 28 and 41 weeks within an Eastern Indian neonate population.(27) In contrast, a cross-sectional study conducted at the neonatology division of a tertiary hospital in Delhi, India observed a moderate correlation between gestational age and the head circumference (r = 0·52), through which a linear regression equation of GA = 19·73+(0·504×HC) was generated.(32) With regards to the strength of association between GA and CHL, our results were in line with the findings of Thawani et al, who observed a moderate association between CHL and GA (r = 0·56).(32)

Contrasting our findings, however, a study conducted in northeast Ethiopia by Tiruneh et al, demonstrated a weak correlation, when assessing both HC and CHL for GA assessment (r = 0.14 and r = 0.115

respectively). These differences might be explained by significant variations in their study population.(33)

Recommendations

Our study brings to light the existing discrepancies in access to resources between high income countries (HIC) and LMICs. Despite extensive efforts to establish stepping stones to health equity—such as the development of Millennium Developmental goals (34) and Sustainable developmental goals (4) by the UN, LMICs lag far behind.(3) This disparity was further exacerbated by the onset of the recent COVID-19 pandemic. (35)

Certain measures can serve to alleviate the problem at hand. One of which is access to basic technology such as ultrasound investigations in a subsidized amount or free of cost, so as to make the resource available to a larger majority. This will, in turn, promote maternal health and antenatal care for infants. Additionally, determining an inexpensive and universal alternative to an ultrasound could serve as an effective measure. Moreover, the work of social workers and medical professionals is more crucial than ever. This includes proper counselling of women regarding the record keeping of LMPs, highlighting the importance of a balanced diet for the mother as well as the infant, and the risks associated with a medically unsupervised pregnancy.

Strengths And Limitations:

While our results have important implications, certain limitations were encountered. This was a single center study, and larger multi-center studies are essential in determining equations for different demographic areas, with precision.

Conclusion

The application of substantial equations to evaluate gestational age through the input of anthropometric measurements could potentially prove to be a break-through in developing nations such as Sudan, where poor assessment of gestational age and subsequent inadequate care lead to high neonatal mortality in preterm babies. However, in order to eradicate the discrepancy observed across various studies regarding the correlation of crown heel length and head circumference of preterm babies with gestation age, comprehensive and multicenter studies must be conducted across diverse populations.

Abbreviations

LDC: least developed countries
GA: gestational age
LMP: last menstrual period
NBS: New Ballard Scoring

HC: Head Circumference
CHL: Crown-heel length
NICU: Neonatal Intensive care unit
WHO: World Health Organization
HIC: High-Income Countries
LMIC: Low-Middle Income Countries

Statements And Declaration

Findings:

Our study included 372 neonates. We noted an increase from 22·5±0·5cm at 25-weeks to 30·5±0·0cm at 36-weeks in Head circumference. Similarly, the crown heel length of our population, was found to increase with gestational age from 33·5±0·0cm at 25-weeks to 46·8±3·3cm at 36-weeks.

Interpretation:

Head circumference and crown heel length correlated well with gestational age (R= 0·704 and 0·810 respectively). The regression equations derived were GA= (the HC)0·504cm+16·3 and GA = (CHL)0·478cm+ 10·936. On multiple regression analysis, the derived equation was GA = (HC)0·197cm + (CHL)0.36cm+9·9.

Ethics Approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics committee of the Omdurman Maternity Hospital.

Consent to Participate

Written Informed consent was obtained from the parents.

Consent to Publish

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

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Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection was performed by Dr. Alaa Hassan Yousif Hamdan. The analysis was performed by Muhammad Mustafa Ali. Ffirst draft of the manuscript was written by Faiza Zakaria, Muhammed Umer, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1: Baseline characteristics of included neonates

	Value N (%)
Number of neonates	372
Gender:	
Males	190 (51·1)
Female	182 (48·9)
Mode of Delivery:	
Vaginal Delivery	187 (50·3)
Cesarean Section	185 (49·7)
Head Circumference:	
AGA	338 (90·9)
LGA	30 (8·1)
SGA	4 (1·1)
Crown Heel Length:	
AGA	329 (88·2)
LGA	37 (9·9)
SGA	6 (1·6)
Preterm Classification	
Extremely Preterm	233 (62·6)
Very Preterm	66 (17·7)
Moderate to Late Preterm	83 (22·3)

Table 2: gestational age-specific mean ± standard deviation (SD) values and confidence interval for head circumference

GA per weeks	mean± SD	Median	95% confidence interval	Minimum value in cm	Maximum value in cm
25 weeks	22·5 ±·5·0	22·5	21·2 - 23·7	22·0	23·0
26 weeks	23·7 ± 1·8	23·0	22·7 - 24·7	21·5	27·5
27 weeks	24·6 ± 1·1	25·0	24·0 - 25·1	22·0	27·0
28 weeks	25·0 ± 4·6	25·5	23·3 - 26·8	21·0	30·0
29 weeks	27·2 ± 1·4	27·5	26·5 - 27·9	23·5	29·5
30 weeks	28·5 ± 1·5	29·0	28·1 - 28·9	22·5	31·5
31 weeks	29·1 ± 1·2	29·0	28·8 - 29·5	26·5	32·0
32 weeks	30·2 ± 1·1	30·5	29·9 - 30·4	26·0	33·0
33 weeks	30·8 ± 0·9	30·7	30·5 - 31·1	29·0	33·0
34 weeks	30·7 ± 0·7	31·0	30·4 - 30·9	29·0	31·5
35 weeks	33·5 ±0·0	33·5	33·5 - 33·5	33·5	33·5
36 weeks	30·5 ± 0·0	30·5	30·5 - 30·5	30·5	30·5

GA: Gestional age

Table 3: gestational age-specific mean ± standard deviation (SD) values and confidence interval for crown heel length

GA per weeks	mean± SD	Median	95% confidence interval	Minimum value in cm	Maximum value in cm
25 weeks	33·5 ± 0·0	33·5	33·5 - 33·5	33·5	33·5
26 weeks	33·6 ± 1·5	33·5	32·8 - 34·5	31·5	37·5
27 weeks	35·5 ± 1·3	36·0	34·8 - 36·1	32·5	37·5
28 weeks	37·6 ± 2·5	37·5	36·7 - 38·6	33·5	42·5
29 weeks	39·3 ± 1·6	39·0	38·5 - 40·1	36·5	42·5
30 weeks	41·5 ± 2·2	41·7	40·9 - 42·0	35·0	47·0
31 weeks	41·2 ± 2·2	41·5	40·5 - 41·8	36·0	45·0
32 weeks	43·2 ± 2·2	44·0	42·7 - 43·7	36·0	49·0
33 weeks	44·9 ± 2	45·0	44·3 - 45·5	39·0	50·0
34 weeks	45·3 ± 1·6	45·0	44·7 - 45·9	41·0	48·0
35 weeks	46 ± 0·0	46·0	46·0 - 46·0	46·0	46·0
36 weeks	46·8 ± 3·3	47·0	42·6 - 50·9	41·0	49·0

GA: gestational age

Appendix

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Figures

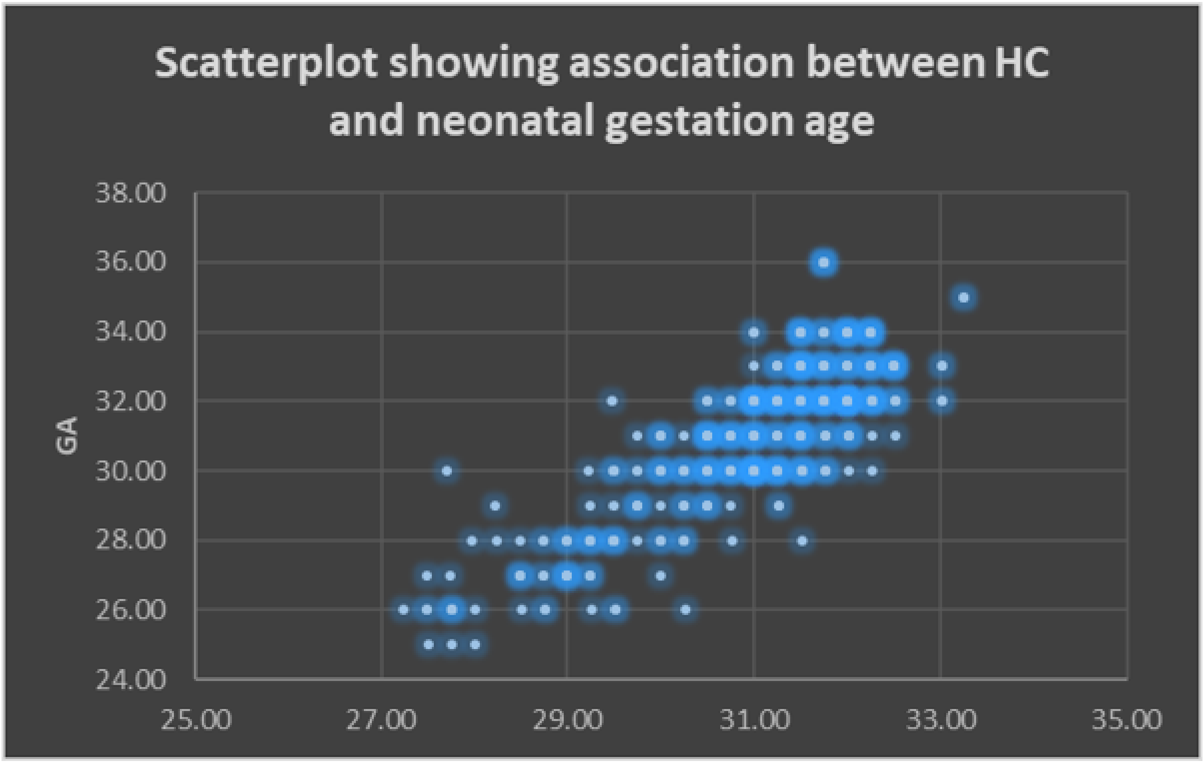

Figure 1

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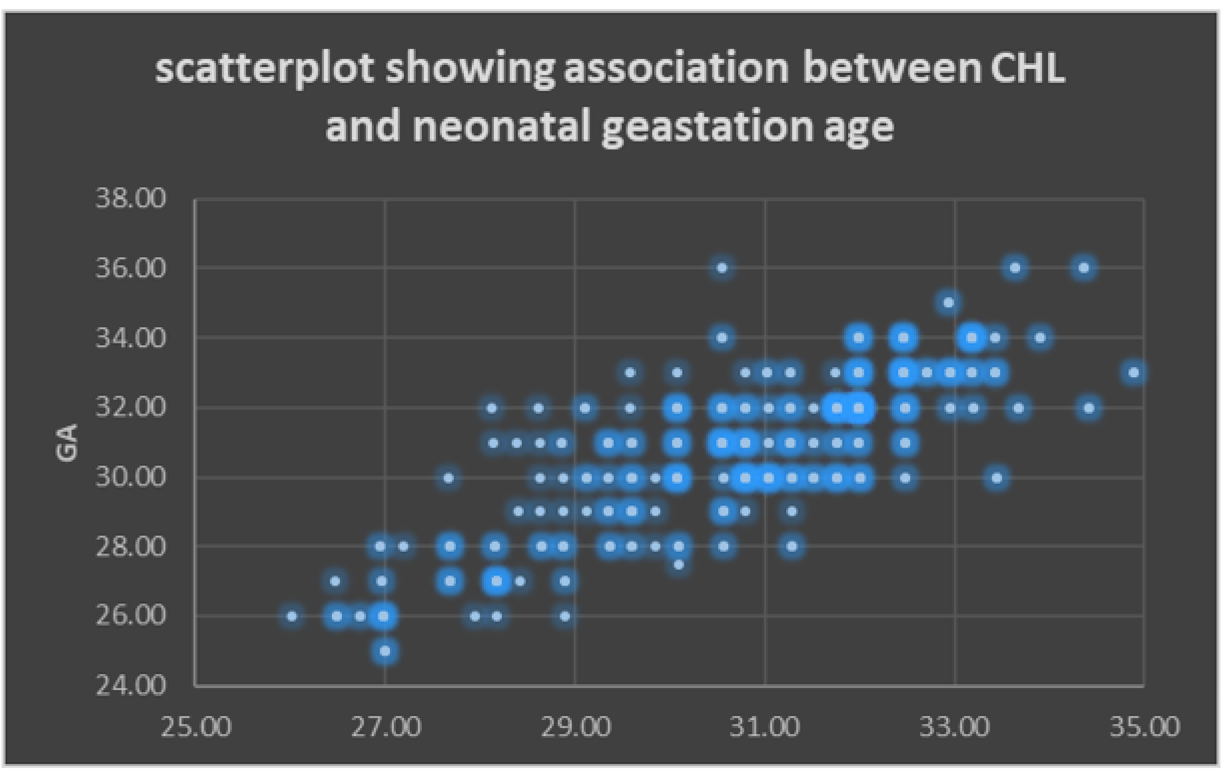

Figure 2

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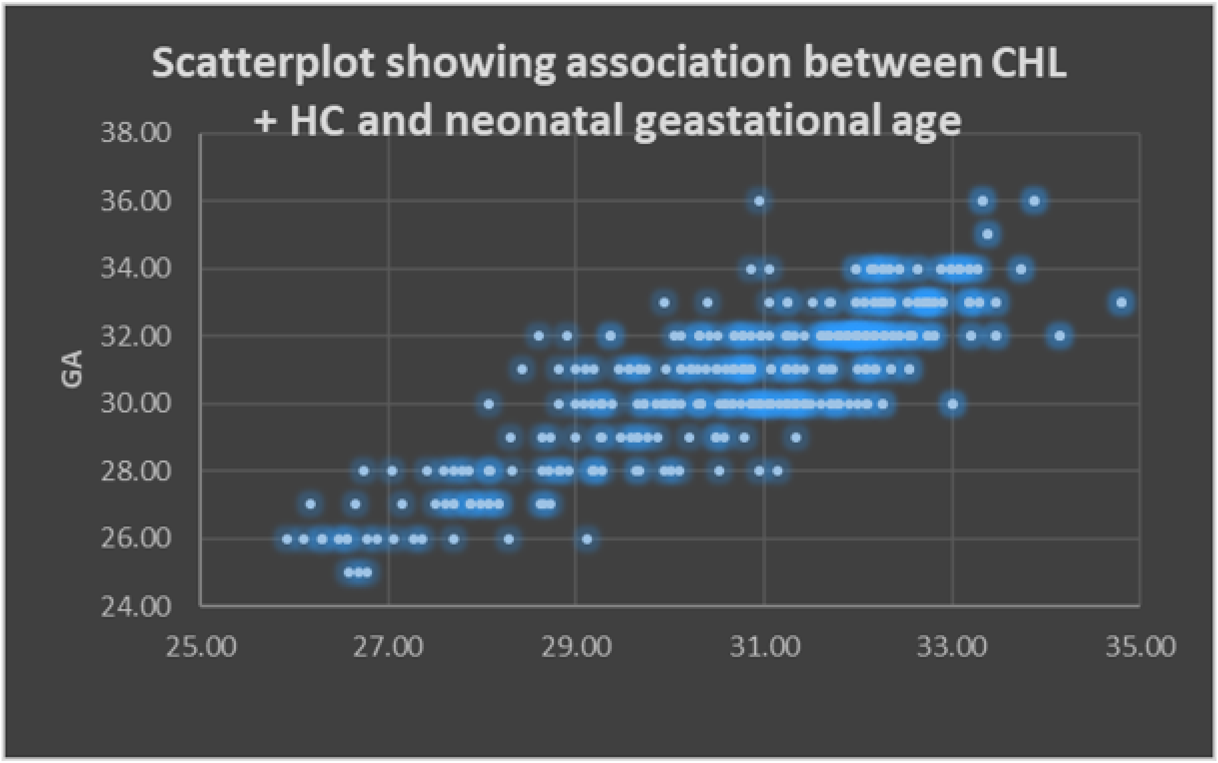

Figure 3

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