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Correlation of Head Circumference with Body Length and Derivation of a Predictive Formula in Indian Infants below 1 Year

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Abstract

Background: Head circumference, an important anthropometric data in infants is usually interpreted based on growth charts. There are few studies on the extent of correlation of head circumference with body length, in comparison to other indices. A predictive formula based on its correlation with length in Indian infants is not available in the literature.

Methodology: This cross-sectional study was carried out on 200 consecutive infants attending well-baby and immunization clinic of a tertiary care teaching hospital in an urban center. All were healthy infants with no neurodevelopmental impairment, and their weight was in the normal range of WHO-MGRS charts. Head circumference and length were recorded thrice by a single observer and an average of three readings was taken. Pearson's correlation between head circumference and age, weight, and body length were determined. A regression equation was derived for estimating head circumference from body length.

Results: The correlation coefficient between head circumference and length was the highest (r=0.929), followed by the correlation of head circumference for weight (r=0.904) and age (r=0.845). The correlation of head circumference with body length was higher in female infants than in male infants. The regression equation of head circumference to body length was derived as Head circumference (cm) = 14.383 + [0.405 × Body length (cm)].

Conclusion: The Head circumference of infants needs to be interpreted as body length. The formula developed from this study will help in early identification of conditions with macrocephaly and microcephaly. It will especially help in infants who are within the normal growth percentiles but have incongruity of head growth compared to body length.

Keywords: Head circumference; Infancy; Coefficient

Introduction

Assessment of growth is the cornerstone of health care in children and a *vital* indicator of a state of health or disease. Head circumference is an important parameter of growth assessment in infancy and early childhood and correlates with neuromotor development. Any deviation of growth of head circumference from normal may be an early sign of neurological disorder, mostly in infants below one year of age. The growth of the skull parallels the growth of long bones and has been correlated with femoral length and body length [1,2]. Work has also been done to correlate head circumference to length in preterm infants [3] and adults [4,5]. There is however no large-scale data on the correlation of head circumference to length in healthy infants and children. Most of such data has been obtained from the Western population and may not be applicable in the Indian context. It is necessary to determine whether head circumference correlates well with body length in infancy, so that interpretation in clinical practice is improved. This study aimed to analyze the correlation between head circumference and body length (height) in healthy Indian infants below the age of one year and to derive a mathematical formula to predict head circumference from a given body length. Also, the study determines whether head circumference correlates better with age or body length in healthy infants below the age of one year.

Material and Methods

This cross-sectional descriptive study was conducted in a tertiary care hospital in western India post obtaining Institutional Ethical Committee clearance for duration of two months among healthy infants including and below the age of one year attending the well-baby clinic and immunization center of the hospital. Our sample size was 200. Institutional ethical committee clearance was obtained prior conduct of the study.

4.1. Inclusion Criteria: All consecutive healthy infants below the age of one year reporting to the well-baby clinic and immunization clinic, as defined by

- Body weight at or above the 3rd percentile of WHO MGRS standards 2006.
- Normal developmental milestones for age.
- No abnormal neurological signs.

4.2. Exclusion criteria

- Infants born with low birth weight (< 2500 gm) or preterm, i.e. before 37 completed weeks of gestation.
- Infants with obvious congenital anomalies.
- Infants with obesity, i.e., weight > 97th percentile for age.

Written informed consents were obtained from the child's parent. The weight of the infant was measured using an electronic weighing scale up to the nearest 10 gm. History of preterm delivery or low birth weight was elicited. A clinical examination was performed to look for any congenital anomaly or abnormal neurological signs. Infants born at term with normal birth weight, with no congenital anomalies or abnormal neurological signs, and with weight corresponding to the 3rd percentile or above of WHO MGRS growth charts were included in the study. The body length of the nude infant was measured using an infantometer. The head of the infant was at the fixed end of the infantometer. Head circumference was measured by passing a non-stretchable fiberglass tape. An average of three readings was determined as the final value. The measurement was made up to the nearest 0.1 cm. The data was recorded on a Performa as attached and entered into an MS Excel sheet. The strength of the linear correlation between head circumference and length, weight, and age was determined by Pearson's correlation coefficient. Correlation coefficients of head circumference to length, head circumference to age, and head circumference to weight were compared for the complete study group, as well as for male and female infants separately. The equation to predict head circumference from length was derived by regression analysis. Intra-observer variation of head circumference and length measurement was determined by finding the intra-class correlation coefficient.

Results

A total of 200 infants below and including the age of 365 days were included in the study. There were 87 female and 113 male infants. The distribution of infants age-wise in the study group is depicted in Figure 1 with most of the infants in the age group of 31 days to 60 days. The range of weight recordings in the infants of the study was 2.5 kg to 9.85 kg. The length was recorded 3 times, and an average was obtained. The intra class correlation coefficient of length recording was 0.999. In the entire study group, the range of average body length ranged from 46.33 to 77.36 cm. The head circumference was also recorded 3 times and an average was obtained. The intra-class correlation coefficient of head circumference recording was 0.998. In the entire study group, the range of average head circumference ranged from 31.63 cm to 45.43 cm. The average head circumference was plotted against the age, average length, and weight using a scatter diagram (Figure 2). The computed slope was 0.405 and the computed intercept was 14.383 for the entire study group. The slope for male and female infants separately was 0.410 and 0.392 respectively. The intercept for male and female infants separately was 14.267 and 14.879 respectively. The correlation of head circumference with body length, age, and weight was calculated by Pearson's coefficient of correlation for the total study group (Table 1) and separately for both sexes (Table 2). In the total study group, the coefficient was highest for head circumference to body length, at 0.929, as compared to weight and age. The correlation coefficient for female infants (0.934) was more than for male infants (0.927).

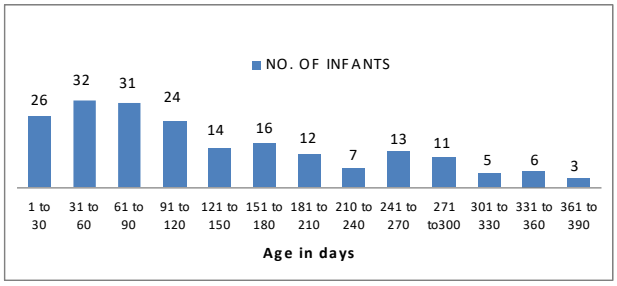

Figure 1: Bar diagram showing age-wise distribution of infants in the study group.

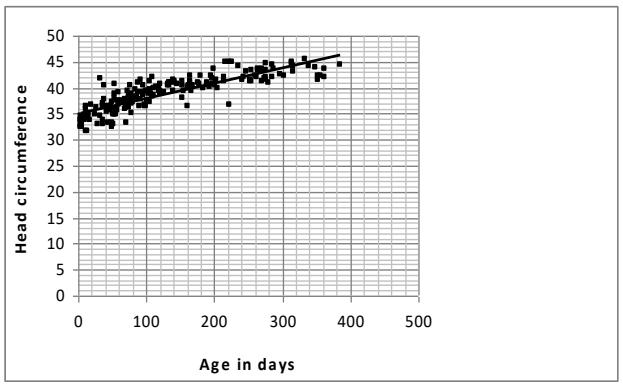

Figure 2: Scatter diagram showing correlation of head circumference with age, body length and weight respectively.

Table 1: Pearson's Correlation coefficient ('r' value) of average head circumference with average body length, age, and weight for the study group.

	Age	**Wt.**	**Average length**
Average Head circumference	.845**	.904**	.929**

**Correlation is significant at the 0.01 level (2-tailed).

Table 2: Pearson's Correlation coefficient ('r' value) of average head circumference with average body length, age, and weight for male and female infants

	Age	**Wt**	**Average length**
Average Head circumference **Male**	.841**	.891**	.927**
Average Head circumference **Female**	.876**	.915**	.934**

**. Correlation is significant at the 0.01 level (2-tailed).

Regression equation was derived for correlation of head circumference with body length in the entire study group, as follows:

Head circumference (cm) = 14.383 (SE: 0.698) + [0.405 (SE 0.011) × Body length (cm)], simplified as

Head circumference (cm) = 14. 4 + [0.4 × Body length in cm]

The regression equation gender-wise was derived as follows:

Male: Head circumference (cm) = 14.267 (SE: 0.973) + [0.410 (SE 0.016) × Body length (cm)]

Female: Head circumference (cm) = 14.879 (SE: 0.979) + [0.392 (SE 0.016) × Body length (cm)]

Discussion

Head circumference is one of the three major anthropometric indices, along with body weight and length, which are used routinely in clinical practice to assess a child's growth [6]. Various growth charts have been derived from various populations, which serve as a reference standard for assessing head circumference. The WHO growth charts of 2006 (Multi-centric Growth Reference Study) are now the internationally applicable norms for reference. There are differences in these standards as the WHO charts reflect the data of developing countries as well as developed countries. The growth of Indian children corresponds more to the standards of WHO growth charts.

Head circumference reflects brain growth in infancy and early childhood. The period of maximum brain growth is in the first two years of life, and head size is an index of brain growth, especially during this period. Zahl SM, et al. [7] found that routine measurement of head circumference as a tool for detecting intracranial expansion in infants was beneficial in detecting hydrocephalus and cysts in the brain. Increased head circumference was the first and main symptom of hydrocephalus, especially in the first 10 months of life [7]. In a study by Bartram JL, et al. [8] measurement of the head circumference by the same observer (intra-class correlation coefficient 0.999) yielded better accuracy than different observers (intra-class correlation coefficient 0.979) [8]. Serial recording of the head circumference should be done by the same observer using the same tape.

Height is measured as body length in infants and denotes skeletal growth. The order of growth is cephalo-caudal and distal to proximal. During fetal life head growth precedes the neck and the growth of arms precedes the legs. The recumbent length is measured in infants using an infantometer. The infant is placed supine on the infantometer, with the vertex of the head firmly in contact with the fixed vertical plank with legs fully extended. In practice, the difficulty of extending the legs may lead to incorrect measurement of the length. Therefore, one should resort to multiple measurements and determine the average.

Yang et al studied the correlation of head circumference with Crown-Rump Length (CRL) in 305 neonatal autopsies and found a high correlation. They derived a predictive formula as follows: Head circumference = 0.9 CRL + 2.5 cm. They found this formula applicable in the newborn period irrespective of age, weight, and race [1].

A similar study was done by Martins et al, who correlated Occipitofrontal Circumference (OFC) with crown-rump length from birth to 15 months of age in a study of 200 infants. Their data indicated that the OFC/CRL ratio can predict if head circumference is in the normal range for a given body size [2].

Saunders CL studied the correlation of head size in the relation to height in 3571 healthy well-nourished children from birth to 5.99 years. Age-adjusted correlation coefficients calculated were HC and height, 0.30; HC and weight, 0.37; and height and weight, 0.60. They proposed a growth standard for head circumference to stature, which could detect relative macrocephaly, an indicator of conditions like hypochondroplasia and achondroplasia [10].

The size of the head also has a genetic influence. Weaver et al studied the familial variation of head size in 122 twin pairs and their parents. They found that 50% of the variation in head size is familiar. They arrived at a method to adjust the predicted head size of the child based on the head size of parents [11]. There are studies in which the relationship of head circumference to length/height has been elaborated [12]. Reference data has also been generated for head circumference for length for preterm low birth weight neonates by Roche AF, et al. [3]. The relationship between head circumference and length in the first 400 days of life was studied by Dine MS, et al [13]. They performed 3144 paired measurements of body length and head circumference on 590 children during the first 400 days of life. Head

circumference correlated well to length, with a correlation coefficient of 0.94, and proposed that infants having head circumference to length discrepancy greater than predicted warrant careful monitoring and investigation. There is a paucity of such studies on Indian infants, who have different growth patterns. Our study was carried out in 200 infants belonging to low to middle socio-economic strata consecutively attending the well-baby and immunization clinic of a large tertiary care teaching hospital.

Most of the infants were in the age group of 31-60 days, followed by 61-90 days which is the period of maximal increase in head circumference. Various measurements were made by a single observer using standard equipment. Any measurement errors were eliminated by an average of three recordings. The intra-class correlation coefficients for length and head circumference recordings were 0.999 and 0.998 respectively, which was like the study by Bartram JL, et al [8].

The range of distribution of body length of infants below 1 year of age in our study conformed to the WHO and CDC chart range. The range of distribution of head circumference in our study group was slightly lower than both WHO and CDC charts. This may be explained by racial differences in the populations. Head circumference was correlated with length, weight, and age by Pearson's correlation. The overall correlation coefficient of head circumference with body length was 0.929. This correlation agrees with the findings of Yang SS, et al and Martins AM, et al [1,2] who found a good correlation between head circumference with crown-rump length. Dine MS, et al [12] found a correlation of 0.94, using a sample of 3144 measurements in infants of age below 400 days. The correlation of head circumference with a length of 0.929 was higher than the correlation for weight (0.904) and age (0.845). We could not access any study in the literature that compared the correlations of head circumference with other anthropometric parameters. However, Eregie CO, et al. [13] found the coefficient of correlation of head circumference to age to be 0.920, which is higher than our study [15]. Our study also found the correlation of head circumference to body length to be different in males and females. In females, the correlation was slightly higher than in males (0.934 *vs.* 0.927).

Based on the strong correlation of head circumference with height, mathematical formulae have been proposed to derive head circumference based on the observed body length. In Yang's study, the predictive formula in the newborn period was HC = 0.9 CRL + 2.5 cm [1]. Dine MS, et al [6] arrived at a formula by regression equation, which was as follows: Head circumference (cm) = 0.448 × length (cm) + 12.766, which was further simplified as Head circumference (cm) = 0.5 × lengths (cm) + 9.5 cm + 2.5 cm. The formula derived from our study is Head circumference (cm) = 14.383 + [0.405 × Body length (cm)], simplified as Head circumference (cm) = 14. 4 + [0.4 × Body length in cm].

This formula has not been reported for the Indian population, to the best of our knowledge. An illustrative comparison of the predicted head circumference based on different body lengths, using our equation and Dine's equation is shown below (Table 3)

Table 3: Comparison of calculated head circumference using two different formulae

Length (in cm)	**Calculated head circumference (in cm) as per equation of Present Study**	**Calculated head circumference (in cm) as per equation of Dine et al study**	**Difference in calculated values (in cm)**
48	33.82	34.27	0.45
60	38.68	39.64	0.96
75	44.75	46.36	1.61

There is a difference in the calculated head circumference, with our formula yielding lower values. This is due to the difference in the reference population, as our children belonged to lower and middle socio-economic strata of a developing country, where the growth standards are lower than the Western population. It is also interesting to note that the predicted head circumference as per our formula is lower than the 50th percentile value for an age corresponding to a given length, as per WHO MGRS charts. The following table is illustrative (Table 4).

Table 4: Comparison of head circumference based on length

Length (in cm)	Calculated head circumference (in cm) as per equation of Present Study	Head circumference (in cm) 50th percentile for corresponding length in WHO MGRS charts	Difference in calculated values (in cm)
60	38.68	39.5	0.82
75	44.75	45.2	0.45

This variation of predicted head circumference in our study from WHO charts may be an indicator that the WHO chart may not be completely appropriate for our Indian population. However, to confirm this trend, a large multi-centric study incorporating all regions of our country will be required. It is therefore important in clinical practice to analyze head circumference about body length which correlates well, as brought out by our study. Our study brought out an easy-to-use predictive formula that can be applied in any busy paediatric outpatient practice and can help in quickly screening infants for any disorder of head growth. There are some limitations to our study. The sample size was limited by the duration of the study, being a student research project. Our study population was not entirely representative of infants across the country and a multi-centric study with a large sample size would yield a better equation.

Conclusion

This study done on 200 infants below the age of one year over a period of two months analyzed the head circumference of other anthropometric parameters and derived a predictive formula for the same. The main conclusions of this study are:

1. Head circumference has a good correlation with age, weight, and body length, but its correlation with body length is the highest as compared to the other two parameters (r = 0.929). The correlation was lowest for age.
2. The correlation of head circumference to length is higher in female infants (r = 0.934) than in male infants (r= 0.927).
3. The head circumference for a given body length can be predicted by a regression equation as follows: Head circumference (cm) = 14.383 + [0.405 × Body length (cm)]. This equation differs slightly in female and male infants. Such an equation has not been reported earlier for Indian infants.
4. The head circumference derived from the formula helps in a better interpretation of the measured head circumference which is incongruous with the other anthropometric parameters. The use of this formula may help in early recognition of conditions such as macrocephaly and microcephaly.
5. A larger multi-centric study in various regions of India would yield a more representative predictive formula.

What is known? Head circumference has a good correlation with age, weight, and body length, but its correlation with body length is the highest as compared to weight and age. What the study adds. The head circumference derived from the formula helps in better interpretation of the measured head circumference which is incongruous with the other anthropometric parameters. The use of this formula may help in early recognition of conditions such as macrocephaly and microcephaly.

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