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Head circumference as an indicator of undernutrition among tribal pre-school children aged 2-5 years of North Bengal, India

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ABSTRACT

Background: *Undernutrition among pre-school children is a major public health issue in the developing countries including India. Head circumference (HC) is a simple, non-invasive and inexpensive anthropometric measure reflecting physical cranial growth and is considered as an indicator of past nutrition status and development of the brain. The present cross-sectional study was carried out to determine the prevalence of undernutrition using the HC among rural pre-school children from North Bengal, India.* ***Materials and Methods:*** *The study was conducted among 447 rural pre-school children (boys: 208; girls: 239) aged 2-5 years who frequented the Integrated Child Development Scheme centers located in Siliguri sub-division of Darjeeling District, West Bengal, India. HC was measured and head circumference-for-age Z-score (HCAZ) was calculated using the age-sex specific L (lambda), M (mu), and S (sigma) values of the WHO Growth Reference. HCAZ values between '−2 to −3' and '<−3' were considered as moderately and severely undernourished, respectively.* ***Results:*** *The overall prevalence of undernutrition using the HC among girls seems to be higher (58.16%) than that in case of boys (53.85%), yet this difference is statistically not significant (p>0.05). The sex-specific overall prevalence of moderate grades of undernutrition was observed to be higher among girls (35.98%) than that of the boys (30.77%) but the difference was not significant (p>0.05). The proportion of severe undernutrition was 22.18% in girls and 23.08% in boys, however, the difference was not significant (p>0.05).* ***Conclusion:*** *The undernutrition is prevalent in more than 50% of 2-5-year old children based on head circumference in this population, however, boys and girls are equally affected. Since HC, brain development and nutrition are all interrelated, steps should be taken in order to improve the nutritional status of these children. The present study recommends routine measurement of HC to assess undernutrition among pre-school children.*

Keywords: Malnutrition, children under five, Head circumference, Undernutrition, ICDS, Anthropometry, Public Health

INTRODUCTION

Undernutrition is considered to be the principal cause of ill-health and premature mortality and morbidity among pre-school children in the developing countries such as India. Anthropometry remains as the single most universally applicable, non-invasive and inexpensive technique of choice for researchers to assess nutritional status of children. A number of anthropometric measurements such as height, weight, mid-upper arm circumference (MUAC), skin fold thicknesses (e.g., triceps and sub-scapular) have been extensively used to assess growth and nutritional status of children (WHO, 2007). A considerable number of scientific literatures have been accumulated over the years using these parameters among children. A simple and non-invasive anthropometric measure is head circumference (HC). Also known as the frontal occipital circumference, HC has been sparingly used to assess the prevalence of undernutrition among pre-school children (WHO, 2007). This circumference is a reflection of cranial growth and is also considered to be an indicator of past nutritional status (e.g., marginal cases of protein energy malnutrition) and development of the brain and brain size (Leiva Plaza et al., 2001; Ivanovic et al., 2004; Singh and Bisnoi, 2005; Laron et al., 2012). It is also one of the most significant findings of the physical examinations, especially in the evaluation of development and early diagnosis of neurological disorders among children (Karabiber et al., 2001; Elmali et al., 2012; Talebian et al., 2013). A rapid increase in HC is also related to the histological changes in the brain during early infancy (Talebian et al., 2013).

Researchers have agreed that HC is a valuable indicator for the assessment of growth and undernutrition among children (WHO, 2007; Anzo et al., 2002; Casey, 2008; Zaki et al., 2008). It had been opined that HC was an important parameter that should be measured more often to determine physical growth and nutritional status among them (Savage et al., 1999). The head growth is most rapid within the first three years of life, primarily owing to the development of the brain. This has prompted the advocation of HC as a routine component of nutritional assessment among children who are at a high nutritional risk (e.g., undernutrition) (Mandal and Bose, 2010; Maiti et al., 2012). However, its potential as a screening measure for undernutrition among children is yet to be fully utilized, although very recently Ramel and Georgieff (2014) have argued that HC can be utilized as a marker of nutritional status. The number of studies using this indicator is far less when compared with those using parameters such as body mass index (BMI) and MUAC. It is only recently that emphasis is being given to HC to determine nutritional status and protein energy malnutrition among children (Ball and Pust, 1993; Mao et al., 1997; Oyedeji et al., 1997; Ivanovic et al., 2004; Zaki et al., 2008). In India, only a handful of studies have been conducted to assess physical growth patterns and prevalence of undernutrition among children using this circumference. Most of the earlier studies had published data on HC along with growth increments in children (Purohit et al., 1977; Bhandari and Ghosh, 1979; Bhargava et al., 1980; Bhalla and Walia, 1993). It is only recently that studies began to be published in the domain of nutritional status among infants and children using HC (Singh and Grover, 2003; Singh and Bisnoi, 2005; Mandal and Bose, 2010; Maiti et al., 2012). Given the above, the present community based study has been conducted to determine age and sex-specific prevalence of undernutrition using the HC among rural pre-school children of North Bengal, India. It also focuses on the potential role of HC in assessing nutritional status among such children.

MATERIAL AND METHODS

The area chosen for the present study is popularly known as North Bengal and lies in the state of West Bengal, India. The region, specially selected is located in the Darjeeling district of the state. A number of tribal (e.g., Lepcha, Rabha, Meche, Toto, Oraon, Santal and Munda) and non-tribal (e.g., Rajbanshi, Bengali Caste and Bengali Muslim) populations inhabit this region. Studies have shown these ethnic populations to be very vulnerable to undernutrition and a high proportion of individuals belonging to these populations were affected by both moderate and severe grades of undernutrition (Mondal and Sen, 2010a,b; Sen et al., 2011; Sen and Mondal, 2012; Tigga et al., 2015a,b). The present cross-sectional study was carried out among pre-school children aged 2-5 years who frequented 16 centers of the Integrated Child Development Scheme (ICDS) located in the rural areas of Sukna, Mohargaon, Matigara and Nishchintapur under Siliguri sub-division of the district of Darjeeling. The children covered in the present study belonged to the Proto-Australoid Tribal Population. Initially, it was the British who were instrumental in bringing individuals belonging to the Proto-Australoid tribal communities (e.g., Santal, Oraon and Munda) from the Chotanagpur plateau of Bihar to North Bengal in the mid-

19th century to be employed as workers in the tea gardens. They are now found in a conglomerate ethnic group collectively referred to as ‘Tea-labourer’ in North Bengal (Bhadra and Chakraborty 1997; Mondal and Sen, 2010a). The ICDS is the largest national program for promotion and development of health of the mother and child and its main beneficiaries are pre-school children, pregnant and lactating mothers and women in the age group of 15-44 years. The scheme provides non-formal pre-school education, supplementary nutrition, immunization, health check-up, referral services, nutrition and health education (Bose et al., 2007; Mandal and Bose, 2010; Tigga et al., 2015a,b).

Prior to data collection, necessary permissions for the study were taken from the ICDS centres and local Panchayets (a village level governing authority). Approval for the study was obtained from the University of North Bengal and the study has been conducted in accordance with the ethical guidelines for human experiments as laid down in the Helsinki Declaration of 2000 (Touitou et al., 2004). The participants were selected using a stratified random sampling method and initially the children were classified the tribal and non-tribal ethnic populations. A total of 505 children (boys: 290; girls: 215) was initially approached to participate in the study. The age and ethnicity of the children were verified from both ICDS centre records and birth certificates. However, 58 of them (boys: 30; girls: 28) were excluded because they did not belong to the population or the age group selected or because their ages could not be verified. So the final sample comprised of 447 pre-school children (boys: 208; girls: 239) in the age group of 2-5 years. All the children were free from physical deformities and were not suffering from any diseases at the time of data collection and presence of such characteristics were excluded to avoid the necessary subject selection bias. The objectives of the study were subsequently explained to either of the parents of the children and an informed consent was obtained from them. The data was collected from September 2014 to January 2015.

Recording head circumference

Head circumference was measured by the standard anthropometric procedures (Hall et al., 2007) using a flexible, non stretch plastic coated Gullick tape. Exerting light pressure, the tape was passed over the glabella to the area near the top of the occipital bone (opisthocranion) as to get the maximum circumference. Care was taken to keep the tape flat against the head and parallel on both the sides. The measurement was recorded to the nearest 0.10 cm. The intraobserver and inter-observer technical errors of the measurement (TEM) were calculated for testing the reliability of the data following the method of Ulijaszek and Kerr (1999). For this, HC was recorded from 50 children other than those selected for the study by two of the authors trained in field investigations and anthropometric data collections (PT and JS). The TEM was calculated using the following equation:

$TEM=\sqrt{(\Sigma D^2/2N)}$, D=difference between the measurements, N=number of individuals.

The co-efficient of reliability (R) was subsequently calculated from TEM using the following equation:

$R=\{1-(TEM)^2/SD^2\}$, SD= standard deviation of the measurements.

Very high values of R (>0.975) were obtained for both intra- and inter-observer TEM and these values were observed to be higher than the cut-off value of 0.95 as recommended by Ulijaszek and Kerr (1999). Hence, the measurements recorded by both of them were considered to be reliable and reproducible. Subsequently, HC in the course of the present study was recorded by one of the authors (PT).

Assessment of Nutritional Status among pre-school children

The age and sex-specific Z- scores value was calculated using the LMS-method. This method is based on three important curves referred to as L (lambda), M (mu), and S (sigma) curves. The M curve is the median or 50th percentile curve, the S curve is a measure of the coefficient of variation, and the L curve is the power of the Box-Cox transformation, which measures the changing skewness of the distribution with age.

The age-specific HC-for-age Z-score (HCAZ) was calculated using the following equation:

$HCAZ=\{(X/M)^L-1\}/(L*S)$. [Where, X=HC, L, M and S are the age-specific values of appropriate table corresponding reference populations].

The Z-score value was calculated using the age and sex-specific WHO child growth reference values (WHO, 2007). The HCAZ value between '−2 to−3' and '<−3' was considered as moderately and severely undernourished, respectively (2007).

Statistical Analysis

The data was statistically analyzed using the Statistical Package for Social Sciences (SPSS version 17.0) and the LMS method software computer program. One way analysis of variance (ANOVA) was done to assess the age and sex-specific mean differences in HC. Chi-square analysis (χ^2) was done to assess sex differences in moderate and severe grades of undernutrition among children. The LMS model is a concept of an age varying adjustment for skewness based on the Box-Cox transformation. The method converts the measurements for a subject of known age and sex to evaluate percentile and standard deviation score or Z-score (Cole and Green, 1992; Cole et al., 1998). The LMS method software computer program fits smooth percentile curves to the reference data using the LMS method as described by Cole and Green (34). The age and sex specific HC percentile curves with 3rd, 10th, 15th, 25th, 50th, 75th, 90th and 97th smoothed percentile lines were plotted separately. A p-value of less than 0.05 and 0.01 was considered to be statistically significant.

RESULTS

The age and sex-specific subject distribution, descriptive statistics and prevalence of undernutrition using the HC among the children is depicted in Table 1. The age-specific mean HC values were observed to be higher among boys than girls, except in girls aged 5 years. The overall mean HC value was significantly higher among boys (46.60±2.46 cm) than girls (45.55±2.46 cm) ($p<0.05$). The mean HCAZ values were observed to be significantly lower among boys than girls, except among those aged 3 years. The mean HCAZ values ranged from −1.35 to −2.92 (for boys) and −0.48 to −2.42 (for girls) aged 2-4 years. The comparison of age-sex specific mean HC of these children with the WHO (2007) reference population is graphically represented in Figure 1. The overall sex difference was observed to be statistically significant in HC (F-value=19.95; d.f., 1; 446; $p<0.01$), but not significant in HCAZ (F-value=0.87; d.f., 1; 446; $p>0.05$). The age-specific mean differences in HC and HCAZ were statistically significant among both boys (F-value=12.53; d.f., 3; 207 and F-value=56.65; d.f., 3; 207) and girls (F-value=21.19; d.f., 3; 238 and F-value=18.47; d.f., 3; 238) using ANOVA ($p<0.01$). The age specific smooth percentile curves derived using the LMS procedure for HC among the children is shown in Figure 2.

Prevalence of undernutrition among the children

The overall (age-sex combined) prevalence of undernutrition (<−2SD) using the HC among girls was observed to be slightly higher (58.16%) than boys (53.85%) (Table 2). The age and sex prevalence of severe grades of undernutrition was lower than the moderate grades of undernutrition among the children. No general age-specific trend in the prevalence of undernutrition was visible among both sexes, but the magnitude was greater among children aged 4-5 years than their younger counterparts (e.g., 2-3 years).

The sex-specific overall prevalence of moderate grades of undernutrition was higher among girls than boys (35.98% vs.30.77%), but the opposite was noticed in case of severe undernutrition (22.18% vs. 23.08%) (Table 2). Age-specific prevalence of overall undernutrition was observed to be higher among 4 years (boys: 77.08%; girls: 70.51%) and lower among 2 years (boys: 21.05%; girls: 28.89%) aged children, respectively. Using $\chi 2$-analysis, the sex differences in the prevalence of overall and age-specific prevalence of undernutrition was found to be statistically not significant ($p>0.05$), except in moderate ($\chi 2$-value=4.26, d.f.,1) and overall ($\chi 2$-value=4.64, d.f.,1) grades of undernutrition among children aged 3 years ($p<0.05$) (Table 2). Though, the prevalence of undernutrition was found to be prevalent in more than 50% of 2-5-year old children based on HC in this population, however, boys and girls are equally affected.

DISCUSSION

Head circumference, a non-invasive and inexpensive anthropometric measure of both nutritional status and brain development, is the most relevant physical index associated with intellectual ability among children (Leiva Plaza et al., 2001; Ivanovic et al., 2004). It has been defined as the most sensitive anthropometric measure of prolonged undernutrition during infancy, associated with intellectual impairment and poor cognitive development (Ivanovic et al., 2004). Any significant reductions in HCs observed in undernourished children may have serious implications for their future performance and achievement (Oyedeji et al., 1997). This circumference is looked upon as one of the most important anthropometric measurements in infancy and early childhood, since it reflects the intracranial volume and brain growth attainment (Hall et al., 2007). Therefore, this measurement became very important for assessment and evaluation of growth and development of children aged below 5 years (WHO, 2007).

The results of the present study reported mean values of HC to be significantly lower among girls than boys ($p<0.01$). Similar studies had earlier reported that mean HC values were significantly lower in girls than boys (Zaki et al., 2008; Oyedeji et al., 1997; Singh and Grover, 2003; Mandal et al., 2010). The age and sex-specific HC mean comparison with the WHO reference (WHO, 2007) showed that most of the children remained undernourished (<-2SD), except girls aged 2 years and 5 years **(Figure 1)**. Some Indian studies have also reported that mean HC values were lower than the WHO/NCHS reference population among urban pre-school children of Faizabad, Uttar Pradesh (Singh and Bisnoi, 2005), Punjabi pre-school children (Singh and Grover, 2003) and Bengalee pre-school of Midnapore, West Bengal (Maiti et al., 2012).

Though the overall prevalence of undernutrition using the HC among girls seems to be higher (58.16%) than that in case of boys (53.85%), yet this difference is statistically not significant ($p>0.05$) (Table 2). On the contrary, some studies have reported that prevalence of undernutrition to be higher among girls than boys. Mandal and Bose (2010) reported high prevalence of undernutrition (boys: 64.90%; girls: 62.80%) among rural pre-school children of Hooghly district of West Bengal. Significantly lower prevalence of undernutrition ($p<0.05$) was reported among Bengalee pre-school boys of Midnapore, West Bengal (boys: 19.20%; girls: 22.60%) by Maiti et al. (2012) ($p<0.05$). However, Sukanya et al. (2014) in their study among pre-school children of urban slums from Karnataka observed that boys were more affected than girls (boys: 37.03%; girls: 28.23%) ($p<0.05$). Several studies have reported that gender differences in the prevalence of undernutrition were more pronounced in poor socio-economic groups and lower segments of the tribal populations with girls being more undernourished than boys (Bose et al., 2007; Mondal and Sen, 2010a; Sen and Mondal, 2012; Maiti et al., 2012; Tigga et al., 2015a,b). Such high prevalence of undernutrition may be attributed to the fact that the children residing in rural areas have poor access of healthcare facilities, literacy and socio-economic conditions (Ball and Pust, 1993; Mondal and Sen, 2010a; Sen and Mondal, 2012; Tigga et al., 2015a,b). The age-specific magnitude of undernutrition was greater among children in the higher age groups (e.g., 4 years and 5 years). Similar trends in the age-specific prevalence were reported among urban slum pre-school children of Karnataka (Sukanya et al., 2014) and Bengalee pre-school children of Midnapore, West Bengal (Maiti et al., 2012).

Conclusion

The result of the present study reflects the high risk of undernutrition among pre-school children of North Bengal. As HC is related to the brain development, cognitive development, learning and nutrition are all interrelated, therefore initiatives should be taken to improve nutritional status of these children. The results showed that moderate undernutrition was more prevalent than severe undernutrition and that girl were observed to be more nutritionally vulnerable. The intervention programmes should, therefore, focus on improving the nutritional status these children along with a regular monitoring of their health so as to achieve their optimal physical growth potentials. The present study further advocates the use of HC to assess nutritional status of children as a routine practice. Moreover, HC is simple to use, non-invasive, objective and easy to record with minimal equipment to determine undernutrition in clinical and field investigation.

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Table 1: Age and sex-specific distribution and descriptive statistics among the children

Age groups	Sample Size		Descriptive statistics (Mean±SD)			
			HC (cm)		HCAZ	
	Boys	Girls	Boys	Girls	Boys	Girls
2 years	**38**	**45**	48.48 ±3.91	45.22 ±2.09	−1.35 ±3.15	−0.48 ±1.62
3 years	**62**	**63**	46.59 ±1.52	44.31 ±1.33	−1.52 ±1.14	−2.53 ±1.09
4 years	**48**	**78**	45.53 ±1.75	45.37 ±1.79	−2.92 ±1.21	−2.42 ±1.29
5 years	**60**	**53**	46.29 ±1.87	47.57 ±3.50	−2.86 ±1.27	−1.52 ±2.39
Total	**208**	**239**	46.60 ±2.46	45.55 ±2.52	−1.70 ±2.32	−1.89 ±1.79

± standard deviation, HCAZ- HC for-age z-score

Table 2: Age and sex-specific prevalence of undernutrition using HC among the children

Age groups	Sample Size		Prevalence of undernutrition using HC					
			Severe (<-3SD)		Moderate (-2SD to-3SD)		Overall (-2SD)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
2 years	**38**	**45**	02 (5.26)	05 (11.11)	06 (15.79)	08 (17.78)	08 (21.05)	13 (28.89)
3 years	**62**	**63**	10 (16.13)	17 (26.98)	12* (19.35)	27* (42.85)	22* (35.48)	44* (69.84)
4 years	**48**	**78**	15 (31.25)	20 (25.64)	22 (45.83)	35 (44.87)	37 (77.08)	55 (70.51)
5 years	**60**	**53**	21 (35.00)	11 (20.75)	24 (40.00)	16 (30.19)	45 (75.00)	27 (50.94)
Total	**208**	**239**	48 (23.08)	53 (22.18)	64 (30.77)	86 (35.98)	112 (53.85)	139 (58.16)

Values are in parenthesis indicates percentages, *p<0.05

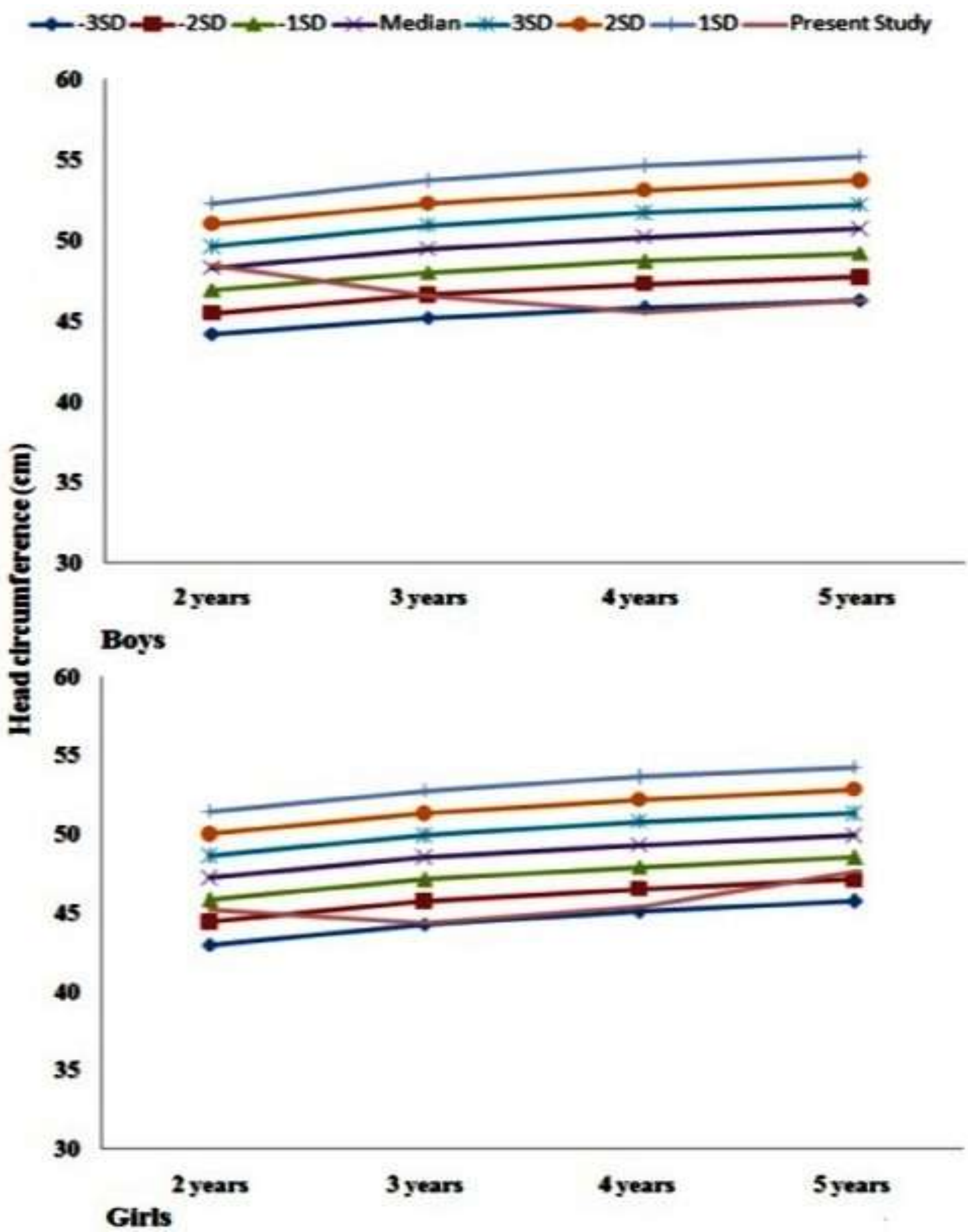

Figure 1: Age-sex specific mean HC comparison with the WHO (2007) Reference population

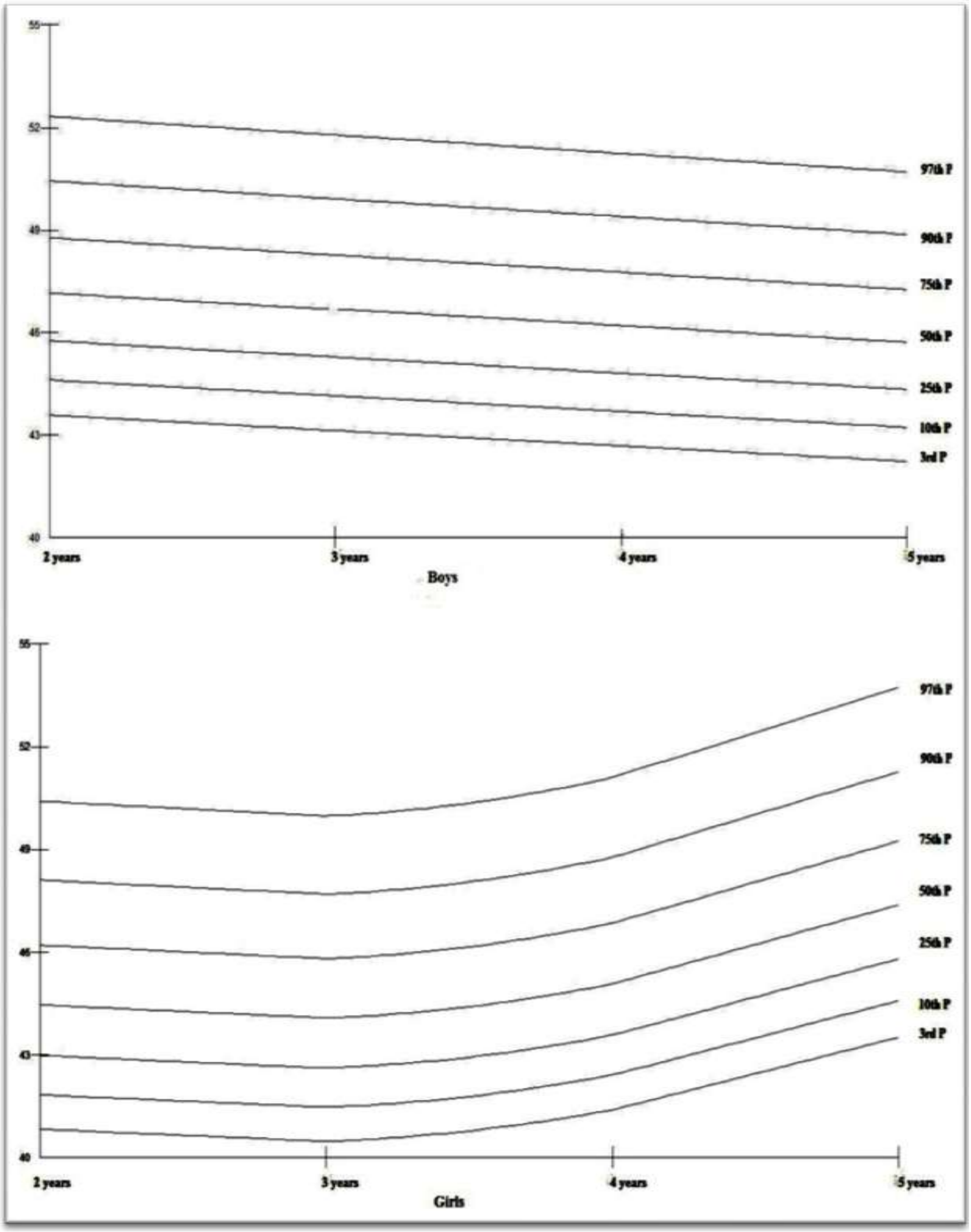

Figure 2: Age and sex-specific LMS percentile curves of HC (cm)