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ABSTRACT: *Measuring linear body segments for studying the growth of any individual anthropometric measurements have been an important tool from earliest times to the present days. The current investigation was cross sectional study undertaken among 1040 (boys=525; girls=515) Bengalee children aged 2-5 years in the Jalpaiguri district of West Bengal, India. There were 40 ICDS centres were selected randomly for the study. This study aims to investigate the age and sex variation of linear body segments such as Height, Sitting Height, Sitting Height/Height, Sitting Height/Sub Ischial Leg Length, Sub Ischial Leg Length, Sub ischial leg length Percentage, Upper Trunk Length and Upper Trunk Length Percentage. The study reveals that sex-specific age variation was found for all linear body segment variables except for the boy's Body Mass Index. There was significant sexual dimorphism observed for some anthropometric variables such as Height, Sitting Height, Upper Trunk Length and Sitting Height/Sub-Ischial Leg Length. Sub Ischial Leg Length Percentage shows a negative correlation with Body Mass Index among both sexes whereas Upper Trunk Length Percentage shows a positive correlation with Body Mass Index among both sexes. The correlation of sub-ischial leg length with Upper Trunk Length, Upper Trunk Length Percentage and Sitting Height/Sub-Ischial Leg Length was observed in all age groups among both sexes. Correlation of Sitting Height with Sub ischial leg length was also observed at every age group for both sexes. The findings of the present study may help to determine the sex and age variations on linear body segments during growth among children.*

Keywords: *Linear Body Segments, Sitting height, Body Mass Index, Sub Ischial leg length, Upper trunk length, Sub Ischial leg length percentage, Upper trunk length percentage.*

INTRODUCTION

Measuring linear body segments for studying the growth of any individual anthropometric measurements becomes an important tool. The upper-lower segment ratio is an anthropometric measurement that is often used to detect the presence of abnormal growth. The period between 0 and 4 years of age is considered a nutritionally dependent phase of growth and during this period, growth occurs predominately in the head and the legs (Prokopec et al. 2001; Lejarraga 2002; Dangour et al. 2002). Height estimation from the measurements of different body dimensions, particularly upper and lower extremities are quite age-old investigations over centuries (Ozaslan et al. 2003). The measurement of sitting height helps to define the body proportion and body segments of any individual. Every country should have its normal data set on standing height, and sitting height used as a national reference (Wacharasindhu et al. 2002). The upper-lower segment ratio is utilized for growth measurement in children. Body segment measurements are often used to detect the presence of abnormal growth during childhood, especially in school children (Behrman et al. 2007). Several factors, such as age, gender, and race influence the upper-lower segment ratio. (Hall et al. 2006). To detect the presence of abnormal growth, especially in school-aged children, the measurement of upper lower segment ratio is a component of growth anthropometric measurement in children (Hall et al. 2006). Several factors, including age, gender, ethnicity, genetics, and environment, influence the growth of the body (Mittal et al. 2021). There are intricate interactions between genetics and the environment that influence body proportions, and the environment has a stronger influence on the growth of extremities than genes (Jelenkovic et al. 2016; Mittal et al. 2021). This can affect the psychosocial aspect of school-age children (Cheng et al. 1996). The diagnostic work-up of children with exceptionally short or tall stature, the visual inspection, and objective measurement of body proportions can give important clues (Gerver & De Bruin 1995; Cheng et al. 1996). Body proportions for the reference charts of sitting height (SHT), sub-ischial leg length (SILL) and sitting height/Sub Ischial Leg Length (SHT/SILL) are useful tools for clinicians and researchers in related areas (Zhang & Li 2015). The usual method of judging body proportions of children is to calculate the ratio between sitting height and height (SHT/HT) to compare this with age references (Fredriks et al. 2005). Sitting height can also be used as a proxy of stature growth (Fredriks et al. 2005). Since stature is an additive measurement, it would be useful to examine the pattern of its constituent segments sitting height (SHT) and sub-ischial leg length (SLL) could be used for evaluation and insight into various growth-related issues (Ghosh & Bandyopadhyay 2005). It is noticed that height HT, SHT, SILL, and other traits have positive secular trends which are pronounced among boys, and the increase in SILL has contributed more than (UTL) Upper trunk length (Dasgupta et al. 2015). A longitudinal study for 3 consecutive years among individuals observed that short leg length, a marker of early childhood deprivation, may increase the risk of developing diabetes (Johnston et al. 2013). Anthropometric measurements were used for various purposes for studying growth patterns, identifying sexual dimorphism, assessing nutritional status, body composition, relation to various physical as well as metabolic diseases, and so on (Mandal & Bose 2020).

After an extensive literature survey, it was found that there was no study on linear body segments for studying the age and sex-specific relationship of linear body segments of preschool children in Maynaguri, Jalpaiguri, West Bengal, India. So, the present investigation was undertaken to investigate the age and sex variation of linear body segments such as Height (HT), Sitting Height (SHT), Sitting Height and Height Ratio (SHT/HT), Sitting Height/Sub Ischial Leg Length (SHT/SILL), Sub ischial leg length (SLL), Sub ischial leg length Percentage (SLLP), Upper Trunk Length (UTL) and Upper Trunk Length Percentage (UTLP).

MATERIAL METHODS

A cross-sectional study was conducted among 1040 children (boys=525; girls=515) aged 2-5 years in Jalpaiguri District of West Bengal. There were 40 ICDS centres were selected randomly for the study. The age and ethnicity of the participants were verified from the polio cards provided by Anganwadi workers. All the participants were of Bengalee ethnicity Necessary permission was taken from the CDPO of Maynaguri Block and approval was granted from the University of North Bengal before the data collection.

The anthropometric data collection was carried out by the first author (AB) following the standard methods. Height and sitting height vertex were measured by using an anthropometer. The SILL was derived by subtracting the sitting height vertex from the total height. The UTL was calculated by subtracting the SILL from the total height. UTL was utilised to calculate UTLP. The percentages of these two derived variables (SILLP & UTLP) were estimated in terms of the % ratio of the total height. The Body Mass Index (BMI, kg/m^2) was calculated by the standard formula: Weight (kg)/Height (m^2).

The statistical analysis was done on a statistical package for social science (version 18) where $p<0.5$ was considered statistically significant. The t-test and analysis of variance (ANOVA) were undertaken to determine sex differences and age variations of anthropometric variables respectively. Pearson's correlation coefficient (r) was used to study the association between BMI, SILL, and SHT with different upper and lower body segments among preschool children.

RESULTS

Table 1 presents the sex and age-specific mean (SD) differences of the variables among the studied children. In the case of height, significant sex differences were found at all ages for age 2 years (t=2.303; p<0.05), for age 3 years (t=3.743; p<0.001), and for age 4 years (t=2.770; p<0.05) except for age 5 years. Considering SHT significant sex difference was found in all ages for 2 years (t=2.921; p<0.01), 3 years (t=3.566; p<0.001), 4 years (t=3.914; p<0.001) and 5 years (t=3.179; p<0.01) respectively. In the case of SHT/HT, there are no significant sex differences in any age group. SHT/SILL shows significant sex differences in the age groups 4 and 5. Whereas for SILL only age 3 years shows significant sex differences (t=2.696; p<0.05). Consideration of UTL shows significant sex differences in all ages for 2 years (t=2.291; p<0.01), for 3 years (t=3.566; p<0.001), for 4 years (t=3.914; p<0.001) and 5 years (t=3.185; p<0.01). But in the case of SILLP, UTLP and BMI there are no significant sex differences at any age group. On the other hand, sex-specific age variation was found for all linear body segment variables, such as HT, SHT, SHT/HT, SHT/SILL, SILL, SILLP, UTL, UTLP except for BMI among boys. Whereas, for girls all body segment variables such as HT, SHT, SHT/HT, SHT/SILL, SILL, SILLP, UTL, UTLP and BMI respectively shows significant age variation among the current study.

1. **Age & Sex variation of Linear Body segments among Bengalee preschool children of Jalpaiguri**

Variables	Sex	Age (Years)					F
		2 (n=250)	3 (n=268)	4 (n=306)	5 (n=216)	Age Combined	
HT (cm)	Boys	86.72 (5.10)	93.97 (4.56)	101.72 (4.96)	108.50 (5.42)	97.57 (9.43)	444.468***
	Girls	85.24 (5.06)	91.85 (4.72)	100.09 (5.23)	107.11 (5.83)	95.73 (9.33)	381.808***
	t	2.303*	3.743***	2.770*	1.798	3.136**	
SHT (cm)	Boys	50.36 (2.52)	52.79 (2.47)	56.64 (2.97)	59.39 (3.13)	54.73 (4.39)	260.139***
	Girls	49.44 (2.47)	51.65 (2.72)	55.35 (2.73)	58.01 (3.19)	53.48 (4.16)	215.591***
	t	2.921**	3.566***	3.914***	3.179**	4.642***	
SHT/HT	Boys	.583 (.01)	.562 (.01)	.557 (.020)	.547 (0.16)	.562 (.02)	84.962***
	Girls	.580 (.01)	.562 (.02)	.553 (.01)	.545 (.02)	.560 (.02)	107.279***

	t	.334	-.285	1.947	2.571	1.566	
SHT/SILL	Boys	1.39 (.09)	1.28 (.08)	1.26 (0.93)	1.21 (0.71)	1.28 (.10)	96.198***
	Girls	1.38 (0.97)	1.29 (0.11)	1.24 (.06)	1.18 (.07)	1.27 (.11)	107.638***
	t	.767	.679	.023*	.009**	1.544	
SILL (cm)	Boys	36.35 (3.09)	41.18 (2.91)	45.07 (3.44)	49.10 (3.20)	42.84 (5.59)	367.901***
	Girls	35.79 (3.14)	40.19 (3.09)	44.73 (3.09)	49.10 (3.36)	42.24 (5.65)	360.825***
	t	1.410	2.696*	.898	.029	1.698	
SILLP	Boys	41.86 (1.59)	43.79 (1.63)	44.28 (2.04)	45.24 (1.52)	43.78 (2.10)	84.962***
	Girls	41.93 (1.70)	43.73 (1.98)	44.66 (1.36)	45.81 (1.66)	43.99 (2.14)	107.285***
	t	-.334	.285	-1.908	-2.593	-1.566	
UTL (cm)	Boys	50.36 (2.52)	52.79 (2.47)	56.64 (2.97)	59.39 (3.13)	54.73 (4.39)	260.139***
	Girls	49.44 (2.47)	51.65 (2.72)	55.35 (2.73)	58.01 (3.19)	53.48 (4.16)	215.591***
	t	2.291**	3.566***	3.914***	3.185**	4.613***	
UTLP	Boys	58.13 (1.59)	56.20 (1.63)	55.71 (2.04)	54.75 (1.52)	56.21 (2.10)	84.962***
	Girls	58.06 (1.70)	56.26 (1.98)	55.33 (1.36)	54.18 (1.66)	56.00 (2.14)	107.286***
	t	.334	.776	1.908	2.571	1.512	
BMI (kg/m^2)	Boys	15.28 (1.58)	14.83 (1.63)	14.74 (1.98)	14.77 (2.01)	14.90 (1.82)	2.558^{NS}
	Girls	15.39 (1.66)	14.77 (1.69)	14.34 (1.62)	14.53 (1.85)	14.74 (1.73)	9.368***
	t	-.520	.255	1.930	.892	1.484	

*P<0.05; **p<0.01; ***p<0.001; NS=Not Significant

Table 2 describes the correlation coefficient of BMI with SILL, SILLP, UTL, and UTLP. In boys, SILL negatively correlated (r=-.252, p<0.05) with BMI only at the age of 3 years but among girls, a significantly negative correlation was found (r=-.178, p<0.01) for overall age. For boys, SILLP for age 3 years (r=-.202, p<0.05) and 5 years (r=-.270, p<0.05) were significantly negatively correlated and for girls aged 2 years (r=-.239, p<0.05) and 4 years (r=-.285, p<0.05) were significantly negatively correlated with BMI. A significant positive correlation was observed for UTL at the age of 4 years (r=.256, p<0.05) and 5 years (r= .490, p<0.01) among boys whereas a significant positive correlation of UTL in the age of 2 years (r= .272, p<0.05), 4 years (r= .170, p<0.05) and 5 years (r= .337, P,0.01) for girls. UTLP shows a significant positive correlation with BMI at the age of 3 years (r=.202, p<0.05) and 5 years (r=.270, p<0.05) among boys, whereas at the age of 2 years (r=.239, p<0.05) and 4 years (r= .285, p<0.01) among girls. However, SILLP shows a negative correlation with BMI in the age group of 3 and 5 for boys whereas in the age group of 2 and 4 for girls. Overall SILLP shows negative correlation among both sexes whereas UTLP shows a positive correlation with BMI among both sexes.

2. **Correlation coefficient of BMI with SILL, SILLP, UTL and UTLP among boys and girls.**

Variables	Boys					Girls				
	2 Yrs. (n=129)	3 Yrs. (n=134)	4Yrs. (n=146)	5 Yrs. (n=116)	Over all (n=525)	2 Yrs. (n=121)	3Yrs. (n=134)	4 Yrs. (n=160)	5 Yrs. (n=100)	Over all (n=515)
SILL (cm)	-.050	-.252*	.147	.140	-.074	-.028	-.149	-.105	.190	-.178**
SILLP	-.092	-.202*	-.023	-.270*	-.170**	-.239*	-.169	-.285**	-.066	-.271**
UTL (cm)	.038	-.116	.256*	.490**	0.53	.272*	.045	.170*	.337**	-.018
UTLP	.092	.202*	.023	.270*	0.170**	.239*	.169	.285**	.066	.271**

*p<0.05; **p<0.01.

Table 3 describes the sex-specific correlation coefficient of SILL with UTL, UTLP, SHT/SILL and SHT/HT. All age group shows a significantly positive correlation of UTL (p<0.01) with SILL among both sexes except for boys at the age of 4 years (p<0.05), whereas a significant negative correlation of UTLP (p<0.01) was found with SILL among both sexes. For SHT/HT shows a negative correlation with SILL only at the age group of 4 among boys. In the case of SHT/SILL (p<0.01), a significant negative correlation was found among both sexes.

3. **Correlation coefficient of SILL with UTL, UTLP, SHT/HT and SHT/SILL among boys and girls.**

	Boys	Girls

Age (Years)	UTL (cm)	UTLP	SHT/HT	SHT/SILL	UTL (cm)	UTLP	SHT/HT	SHT/SILL
2 (n=250)	.647**	-.819**	-.094	-.824**	.615**	-.834**	-.039	-.839**
3 (n=268)	.431**	-.778**	-.079	-.782**	.315**	-.760**	-.094	-.763**
4 (n=306)	.192*	-.800**	-.202*	-.807**	.612**	-.712**	-.038	-.713**
5 (n=216)	.466**	-.668**	.156	-.670**	.485**	-.713**	-.062	-.722**

*p<0.05; **p<0.01.

Table 4 describes the correlation coefficient of Sitting Height with SILL, SILLP, UTL, UTLP. All the ages separately show a significant correlation ($p<0.05$) of SILL with Sitting Height among both sexes but not all age groups in the case of SILLP. According to SILLP, ages 3 years, 4 years and 5 years show a significant negative correlation with Sitting Height respectively among boys, whereas ages 3 years and 5 years show a significant negative correlation with Sitting Height among girls.

4. Correlation coefficient of Sitting Height with SILL, SILLP among boys and girls.

Age (Years)	SILL (cm)		SILLP	
	Boys	Girls	Boys	Girls
2 (n=250)	.647**	.615**	.095	.081
3 (n=268)	.431**	.315**	-.229*	-.374**
4 (n=306)	.192*	.612**	-.434**	-.118
5 (n=216)	.466**	.485**	-.346**	-.264*

*p<0.05; **p<0.01.

DISCUSSION

Here we have tried to study sex-specific age variation on linear body segments among Bengalee preschool children aged 2-5 years in Jalpaiguri, West Bengal, India. All linear body segment variables such as HT, SHT, SHT/HT, SILL, SILLP, UTL, and UTLP showed significant age variations among Bengalee children. There was significant sexual dimorphism observed for some anthropometric variables such as HT, SHT, UTL and SHT/ SILL showing significant sex differences in most of the age groups.

Age and sex-specific determination of body segments provide useful information about disproportionate body stature. Furthermore, decreased linear body segment can be a reason for abnormality of trunk length and leg length. There is a significant racial difference in upper lower segment ratio, where Caucasians and African Americans have a longer leg than Asians (Hall et al. 2006). Studies show when Asian was compared to Caucasians and African Americans, Asians were more likely to have a higher upper-lower segment ratio in the same age but among children during the growth and development phase, it may be unpredictable. The secular increase in height was due to increased sub-ischial leg length that can affect the lower segment as well as the upper-lower segment ratio (Kagawa & Hills 2011). Study reveals that the upper-lower segment ratio decreases gradually from age 7 to 10 in both obese and normal children (Azhar et al. 2016) but in our study, SILL and UTL increase gradually from age 2-5 years. The age influences on upper lower segment ratio also seen in the body proportion among Dutch children aged 0-21 (Fredrik et al. 2005) but in the present study, we observed body segment ratio decreases gradually with increasing age. Various studies have shown that the positive secular change is mainly due to an increase in leg length rather than in trunk length (Tanner et al. 1982; Bogin et al. 2002; Dangour et al. 2002). The increases in height over the years in different populations are mainly due to the increase in leg length but not due to trunk length (Jantz and Jantz 1999, Dangour et al. 2002), leg length is highly influenced by nutritional conditions during the developmental phase of growth (Kinra et al. 2011). The mean height, weight, and sitting height ratio for each group differ between a small city and a moderate city. A previous study revealed that after immigration from small cities to moderate cities Maya children in the United States were significantly taller at all ages than Maya children in Guatemala (Bogin et al. 2002) may be a reason for environmental (urban or rural) background, in our study children belongs to rural background. A study on children, adolescents and adults in America reported that UTL is a better predictor for BMI than SILL (Burton 2018), in the present study UTL was significantly correlated at the age of 4 and 5 for boys whereas at the age of 2, 4 and 5 for girls but not in the case of SILL supported the previous study. Our study focused on only one ethnic group which belongs to the Bengalee ethnicity, the interrelationship of BMI, SHT and SILL with UTL and UTLP may be different for various ethnicities in India as well as globally.

Consideration of increasing age has a positive relationship with most of the body segments similar study reported by Ghosh & Bandyopadhyay (2005) and Mandal & Bose (2020). A study among adult individuals from Naxalbari, Darjeeling District, West Bengal, India (Datta Banik 2016) revealed the sexual dimorphism of HT, SHT, and SLL similar to the present study. Significant sex-specific age variation among all linear body segments same as the previous study done by Mandal and Bose (2020) and sex-specific age variation on HT, SHT, and SLL was similar to Primary School children of Hoogly (Pal & Bose 2017). A significant correlation of SILL with UTL and UTLP was seen in the present study. Moreover, BMI has significantly correlated with SILLP and UTLP among both sexes similar to the previous study done by Mandal & Bose (2020). BMI has no significant association with SILL and UTL for boys and only UTL for girls when age combined is taken into account. A significant correlation between Sitting height and SILL shows similar results to a study done by Ghosh & Bandyopadhyay (2005). A study reported on Turkish children showed a positive correlation between body segments like SILL with UTLP and SILLP similar to the current study. The present study reveals a similar result as Mandal & Bose (2020), SILL was correlated significantly with UTL and UTLP among both sexes, where UTL has a positive correlation but UTLP has a negative correlation. A negative correlation has also been seen among both sexes between SILL and SHT/SILL in the present study.

It should be mentioned here that a major limitation of the present study is the small sample size and the study being confined to a specific region of West Bengal, India. However, there is still limited evidence reported on the linear body segment cut-off values among Indian children as well as globally. Ethnicity-specific further studies in various regions of India are required to overcome these limitations. The strength of the present study is the data reported by the author may be used as age and sex-specific reference values of linear body segments for Indian children. The findings of the present study help to understand the age and sex-specific variation of linear body segments in the tempo of growth at the developmental phase of Bengalee children.

Conclusion

There is significant sex-specific age variation observed in all linear body segments. The correlation of sub-ischial leg length with UTL, UTLP and SHT/SILL was observed in all age groups among both sexes. Correlation of Sitting Height with SILL was also observed at every age group on both sexes. The findings of the present study may help to determine the effect of sex and age on linear body segment variations during growth among children. Thus, these variables can be potentially used to study human population variation analysis of ethnic groups from different environmental backgrounds. The subsequent results obtained from these studies may have immense applications in biological anthropology, particularly in understanding morphological variation within and between the populations.

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