

## **Pre and post pubertal growth difference among boys and girls of 5-18 years of age: A cross sectional study among central Indian Population**

R. Thakur<sup>1</sup> and R.K. Gautam<sup>2</sup>

*Citation: Thakur R and Gautam RK. 2017. Pre and post pubertal growth difference among boys and girls of 5-18 years of age: A cross sectional study among central Indian Population. Human Biology Review, 6 (2), 164-187.*

<sup>1</sup> Rachna Thakur, Department of Anthropology, Dr. H.S. Gour University, Sagar-470003 (MP), India. Research Scientist II, National Aids Research Institute (ICMR), Pune -411026. Email: [trachna4@gmail.com](mailto:trachna4@gmail.com),

<sup>2</sup> Rajesh K. Gautam, Department of Anthropology, Dr. H.S. Gour University, Sagar-470003 (MP), India. Department of Anthropology, Montclair State University, Montclair-07043 New Jersey, USA. International Visiting Scholar (Raman Post-Doctoral Fellow), Centre for Quantitative Obesity Research, Montclair State University, Montclair-07043 New Jersey, USA. Email: [goutamraj@rediffmail.com](mailto:goutamraj@rediffmail.com)

Corresponding author: Rajesh K. Gautam. International Visiting Scholar (Raman Post-Doctoral Fellow), Centre for Quantitative Obesity Research, Montclair State University, Montclair-07043 New Jersey, USA. Email: [goutamraj2006@gmail.com](mailto:goutamraj2006@gmail.com).

*ABSTRACT Objectives: To understand the difference in growth pattern of different body dimensions among boys and girls during pre-pubertal and post-pubertal span of life.*

*Material and Method: A cross-sectional survey was conducted on 612 individual consisting of 312 girls and 300 boys of 5 to 18 years of age; who were recruited from a central Indian town (Sagar). They were measured for ten anthropometric traits viz. stature, sitting height, Body weight, head length, head breadth, head circumference, upper arm circumference, chest circumference, hip circumference and waist circumference.*

*Results: The boys and girls grow almost with same rate upto puberty. During early span of life girls are insignificantly taller and heavier than boys but after puberty the boys become significantly taller and heavier as well as they have overall larger body dimensions than the girls. On the basis of regression analysis, it was found that the growth pattern of height, body weight sitting height, upper arm circumference and head circumference was faster among girls as compared to boys during pre-puberty; whereas, the growth pattern of head length, head breadth and circumferences like chest, waist and hip circumference were faster among the boys. On the contrary, during puberty and after puberty the growth of all above body dimensions and body mass is faster among boys as compared to girls.*

*Conclusion: There is almost no sexual dimorphism in growth pattern of boys and girls upto puberty. After puberty, the boys exceed than girls and sexual dimorphism is apparent.*

**Key words:** *Height, weight, head length, head breadth, sexual dimorphism, regression*

## **INTRODUCTION**

The growth of children in a population reflects their nutritional status and indirectly determines their standard of living. Growth is influenced by diet intake and expenditure on general health condition of an individual. Studies on child growth and development have always occupied an important position in the scientific research curriculum and are of interest to the researchers of both Medical Science and Physical Anthropology (Sharma 1970). A well-designed growth study may provide a powerful tool to identify the health and nutritional status of any population or community.

Linear body dimensions of children and youth predominantly reflect growth of bone (Papelia et al 1989). These dimensions are closely associated with structural and functional changes. For instance, pubertal height velocity is highly related to the menarcheal age and the slowdown of the growth of locomotor system with the onset of growth of the respiratory system (Ellison 1982). As any dynamic system, bone has to maintain a balance of proportions in its permanent change of size and structure (Tanner et al 1976). This process is known to be different in boys and girls during puberty, although growth of children is too complex to be described. Anthropometric measurements are usually the parameter used in the assessment of changes in linear body dimensionality.

It has been already recognized that environmental factors influence body shape (Eveleth and Tanner 1990; Bogin 1988). The changes of body proportions under the influence of improved quality of life are well documented in the Japanese and Polish populations (Tanner et al 1982). In contrast to the trunk and legs, the relative growth of arms has been poorly documented and there are scarcity of data on its sexual dimorphism and variability among populations.

This study is focused on stature, sitting height, body weight, head length, head breadth, head circumference, upper arm circumference, chest circumference, hip circumference and waist circumference for boys and girls of 5-18 years of age, which reflect Sexual dimorphism in human growth from childhood to adolescence. Since growth of stature results from changes in length of upper and lower body segments with age, it is indispensable to include sitting height and limbs length in the analysis of growth. The patterns of relative growth of trunk and lower extremities vary among populations. While accepting a strong environmental component for body size, most scholars have opted for genetic control of body

proportions (Bogin, 1988; Treloar et al.1990 Bogin et al. 2001; Mustanski et al.2004 and Ge et al 2007).

Hence, to understand the difference in growth pattern of different body dimensions among boys and girls during pre-pubertal and post-pubertal span of life. Anthropometric measurements were taken as it is the universally applicable, inexpensive and non-invasive technique available to researchers for the assessment of the size and proportion of the human body (WHO 1995) and is a very useful tool in the assessment of growth and nutrition (Gorstein et al. 1994; Hamieda and Billot 2002). The technique of anthropometry has been successfully utilized by different researchers to assess and document the growth and nutritional status of various human communities, (Sharma and Sharma 1992; Bailey and Ferro-Luzzi 1995; Deurenberg-Yap et al. 2000; Mehta and Shringarpure 2000; Misra et al. 2001; Khongsdier 2002; Rao et al. 2006; Zerfu and Mekasha 2006; Bharati et al. 2007; Semproli and Gualdi-Russo 2007; Bisai et al. 2008; Bose et al. 2008; Chowdhury et al. 2008; Olivieri et al. 2008, Gautam et al., 2006, Gautam 2007 and 2013, Thakur and Gautam 2014 and 2015).

## **SUBJECTS AND METHODS**

The samples for the present study were recruited from fourteen schools of Sagar Town of Sagar district of Madhya Pradesh State of Indian Union. The sample consists of 612 (312 girls and 300 boys), aged 5-18 years of age. The anthropometric measurements were taken during the month of September 2013 to February 2014. In connection with the studies on growth and development the information on correct age of children is extremely important. If the age of children is doubtful the result is completely misleading. For the present study, age was ascertained in completed year of each subject through school admission records. If the sample was 5 year and 6 month old, it refers to 5 year, at the same time, if he refers to 5 year 7 month, then the age was rounded up to 6 year.

A total of 10 anthropometric measurements were taken on each individual following the standard procedure as described by Gibson (1990). The anthropometric measurements of height, weight, sitting height, head length, head breadth, head circumference, upper arm circumference, chest circumference, waist circumference and hip circumference were taken. The measurements were taken with all possible caution maintaining uniformity and accuracy in the techniques, after undergoing extensive training. Portable digital weighing machine, anthropometer rod, tape and spreading caliper were used to measure the various

anthropometric measurements. A detailed description of the study technique is available elsewhere (Thakur and Gautam 2014 & 2015).

Descriptive statistics was used to present substantial characteristics of the data. Comparisons between sexes and successive age cohorts were carried out by using univariate analysis of variance (ANOVA), student *t-test* is used to distinguish between the age cohorts of two sexes, followed by simple linear regression analysis of pre-pubertal and pubertal and post-pubertal cohort of boys and girls.

## RESULTS

Descriptive statistics of body weight, stature, sitting height, head length, head breadth, head circumference, upper arm circumference, chest circumference, hip circumference and waist circumference are presented by age cohorts in Tables 1. To understand the difference between boys and girls *t-test* and Error bar diagramme was used. The error bar diagramme (95% confidence intervals) constructed by age and sex are shown in Figure 1 to 10.

Table 1. Comparison of age wise body mass and dimensions among school going boys and girls of Central India

Age	Mean		Paired Differences			t- value	df	P- value
	Boys	Girls	Mean	SD	SE			
Body mass (in Kgs)								
5	15.3	15.3	0	2.5	0.5	0.118	19	0.907
6	16.5	17.6	1.1	2.9	0.6	1.621	21	0.120
7	18.3	19.2	0.9	4.4	0.9	0.731	21	0.473
8	19.5	20.8	1.3	5.0	1.1	0.958	20	0.349
9	21.9	22.6	0.7	6.0	1.3	0.239	22	0.813
10	24.8	25.0	0.2	5.5	1.2	0.237	20	0.815
11	27.4	28.6	1.2	7.0	1.5	0.669	21	0.511
12	30.7	33.2	2.5	10.5	2.2	0.907	21	0.375
13	33.8	35.8	2	10.4	2.3	0.860	19	0.400
14	37.3	34.7	-2.6	9.7	2.1	-0.838	20	0.412
15	40.0	41.0	1.0	11.0	2.5	0.417	19	0.681
16	46.3	40.2	-6.1	11.2	2.5	-2.425	19	<b>0.025</b>
17	51.1	45.3	-5.8	10.7	2.4	-2.558	19	<b>0.019</b>
18	52.0	43.7	-8.3	7.4	1.7	-5.107	19	<b>0.001</b>
Height (in cm)								
5	103.4	105.8	2.4	9.0	2.0	1.197	19	0.246
6	108.4	111.7	3.3	8.4	1.8	1.927	21	0.068
7	112.9	117.3	4.4	9.4	2.0	1.875	21	0.075
8	118.7	120.4	1.7	9.3	2.0	0.942	20	0.357
9	122.7	125.5	2.8	10.4	2.2	0.780	22	0.444
10	129.6	130.7	1.1	7.7	1.7	0.572	20	0.574
11	134.9	137.2	2.3	10.5	2.2	0.912	21	0.372
12	141.5	142.4	0.9	16.6	3.5	0.215	21	0.832
13	145.2	144.6	-0.6	7.7	1.7	-1.281	19	0.215
14	151.0	145.1	-5.9	10.8	2.4	-2.231	20	<b>0.037</b>
15	156.3	151.4	-4.9	10.2	2.3	-2.143	19	<b>0.045</b>
16	161.2	148.6	-12.6	8.0	1.8	-7.026	19	<b>0.000</b>

17	164.0	153.2	-10.8	13.8	3.1	-3.398	19	<b>0.003</b>
18	166.1	153.0	-13.1	5.8	1.3	-10.513	19	<b>0.000</b>
Sitting Height (in cm)								
5	55.8	56.0	0.2	4.9	1.1	0.104	19	0.918
6	57.5	58.7	1.2	4.9	1.0	0.960	21	0.348
7	60.2	61.7	1.5	4.3	0.9	1.370	21	0.185
8	63.1	63.3	0.2	6.4	1.4	0.027	20	0.978
9	63.9	64.6	0.7	5.1	1.1	0.366	22	0.718
10	67.2	67.6	0.4	4.7	1.0	0.521	20	0.608
11	68.6	70.6	2	5.2	1.1	1.642	21	0.115
12	71.7	72.5	0.8	7.6	1.6	0.355	21	0.726
13	73.9	74.3	0.4	5.8	1.3	0.186	19	0.854
14	76.2	74.5	-1.7	6.2	1.4	-1.028	20	0.316
15	78.6	77.6	-1	6.6	1.5	-0.677	19	0.507
16	82.2	76.5	-5.7	5.7	1.3	-4.441	19	<b>0.000</b>
17	83.8	79.4	-4.4	5.1	1.1	-3.978	19	<b>0.001</b>
18	82.5	78.6	-3.9	7.1	1.6	-2.625	19	<b>0.017</b>
Head length (in cm)								
5	16.7	15.8	-0.9	0.7	0.2	-5.300	19	0.001
6	17.1	16.1	-1	0.7	0.1	-6.733	21	0.001
7	17.0	16.1	-0.9	1.3	0.3	-3.679	21	0.001
8	17.2	16.2	-1	0.7	0.1	-6.708	20	0.001
9	17.3	16.3	-1	0.8	0.2	-6.469	22	0.001
10	17.7	16.1	-1.6	1.0	0.2	-6.974	21	0.001
11	17.7	16.6	-1.1	0.9	0.2	-5.559	21	0.001
12	17.8	16.9	-0.9	0.9	0.2	-5.145	21	0.001
13	18.0	16.9	-1.1	0.6	0.1	-7.347	19	0.001
14	18.2	16.8	-1.4	0.9	0.2	-6.344	20	0.001
15	18.0	16.9	-1.1	0.9	0.2	-5.833	19	0.001
16	18.4	16.8	-1.6	0.8	0.2	-9.595	19	0.001
17	18.8	17.1	-1.7	1.0	0.2	-7.465	19	0.001
18	18.7	17.2	-1.5	0.9	0.2	-8.151	19	0.001
Head breadth(in cm)								
5	12.8	12.7	-0.1	0.7	0.2	-0.419	19	0.680
6	12.8	12.9	0.1	0.6	0.1	0.631	21	0.535
7	13.2	12.9	-0.3	0.8	0.2	-2.063	21	0.052
8	13.2	13.0	-0.2	0.6	0.1	-0.843	20	0.409
9	13.2	13.0	-0.2	0.7	0.1	-1.951	22	0.064
10	13.5	13.0	-0.5	1.1	0.2	-1.838	20	0.081
11	13.3	13.0	-0.3	0.8	0.2	-1.960	21	0.063
12	13.5	13.2	-0.3	0.9	0.2	-1.427	21	0.168
13	13.3	13.1	-0.2	0.7	0.2	-1.137	19	0.270
14	13.5	13.3	-0.2	0.7	0.2	-1.162	20	0.259
15	13.5	13.4	-0.1	0.9	0.2	-0.511	19	0.615
16	13.9	13.4	-0.5	0.8	0.2	-2.640	19	<b>0.016</b>
17	14.1	13.5	-0.6	0.8	0.2	-3.538	19	<b>0.002</b>
18	14.1	13.4	-0.7	0.8	0.2	-3.497	19	<b>0.002</b>

Head circumference (in cm)								
5	49.4	48.9	-0.5	1.8	0.4	-1.198	19	0.246
6	49.9	49.4	-0.5	2.3	0.5	-1.356	21	0.190
7	49.8	49.5	-0.3	2.3	0.5	-.651	21	0.522
8	50.3	49.9	-0.4	1.8	0.4	-1.034	20	0.313

9	50.4	50.8	0.4	2.1	0.4	0.317	22	0.754
10	51.0	51.0	0	2.1	0.5	-0.184	20	0.856
11	51.6	51.5	-0.1	1.8	0.4	-0.209	21	0.836
12	52.0	52.2	0.2	2.7	0.6	0.206	21	0.839
13	52.1	52.5	0.4	2.1	0.5	0.919	19	0.370
14	52.5	52.1	-0.4	1.6	0.3	-0.562	20	0.581
15	52.6	52.8	0.2	2.4	0.5	0.472	19	0.642
16	53.8	53.2	-0.6	2.0	0.5	-1.358	19	0.190
17	55.3	53.7	-1.6	1.8	0.4	-4.342	19	<b>0.001</b>
18	55.2	53.4	-1.8	2.3	0.5	-3.642	19	<b>0.002</b>
Chest circumference (in cm)								
5	51.8	53.7	1.9	4.2	0.9	1.972	19	0.063
6	53.2	56.0	2.8	4.0	0.9	3.057	21	0.006
7	54.5	56.1	1.6	5.0	1.1	1.414	21	0.172
8	55.7	57.7	2	5.3	1.2	1.622	20	0.121
9	57.7	59.8	2.1	6.1	1.3	1.046	22	0.307
10	60.6	61.7	1.1	6.4	1.4	0.734	20	0.471
11	61.8	64.4	2.6	7.5	1.6	1.468	21	0.157
12	64.5	69.7	5.2	8.8	1.9	2.491	21	0.021
13	67.7	70.2	2.5	8.5	1.9	1.173	19	0.255
14	69.1	71.2	2.1	7.0	1.5	1.724	20	0.100
15	70.9	75.6	4.7	8.1	1.8	2.593	19	0.018
16	76.8	76.0	-0.8	8.0	1.8	-0.487	19	0.632
17	79.0	78.6	-0.4	8.0	1.8	-0.434	19	0.669
18	79.7	77.0	-2.7	6.0	1.4	-1.973	19	0.063
Upper arm circumference (in cm)								
5	15.1	15.2	0.1	1.4	0.3	0.319	19	0.753
6	15.3	16.0	0.7	1.5	0.3	1.827	21	0.082
7	15.4	16.1	0.7	2.0	0.4	1.677	21	0.108
8	16.0	16.6	0.6	2.0	0.4	1.093	20	0.287
9	15.9	17.1	1.2	1.9	0.4	2.963	22	<b>0.007</b>
10	17.3	17.7	0.4	2.0	0.4	1.100	20	0.284
11	18.0	18.6	0.6	2.2	0.5	1.111	21	0.279
12	18.3	19.5	1.2	2.7	0.6	1.954	21	0.064
13	19.2	20.3	1.1	3.4	0.8	1.420	19	0.172
14	19.6	19.8	0.2	2.9	0.6	0.628	20	0.537
15	20.1	21.0	0.9	2.8	0.6	1.567	19	0.134
16	22.0	21.4	-0.6	3.0	0.7	-0.973	19	0.343
17	23.3	22.4	-0.9	2.7	0.6	-1.354	19	0.192
18	24.0	22.4	-1.6	3.0	0.7	-2.477	19	<b>0.023</b>
Hip Circumference /Girth (in cm)								
5	53.8	57.6	3.8	5.0	1.1	3.413	19	<b>0.003</b>
6	55.4	58.7	3.3	4.5	1.0	3.439	21	<b>0.002</b>
7	57.1	60.1	3	5.9	1.3	2.200	21	<b>0.039</b>
8	58.0	60.8	2.8	6.0	1.3	2.067	20	<b>0.052</b>
9	60.3	62.4	2.1	7.5	1.6	1.482	22	0.152
10	62.9	65.0	2.1	6.5	1.4	1.539	20	0.140
11	65.5	68.6	3.1	7.4	1.6	1.920	21	0.069
12	67.2	71.9	4.7	7.1	1.5	2.807	21	<b>0.011</b>
13	69.1	74.9	5.8	9.7	2.2	2.602	19	<b>0.017</b>
14	71.2	74.9	3.7	8.6	1.9	2.251	20	<b>0.036</b>
15	73.0	78.3	5.3	6.6	1.5	3.562	19	<b>0.002</b>
16	78.1	78.8	0.7	9.6	2.2	0.313	19	0.757
17	82.1	81.2	-0.9	7.9	1.8	-0.738	19	0.470

18	81.0	80.9	-0.1	6.4	1.4	-0.035	19	0.973
Waist circumference (in cm)								
5	48.4	52.1	3.7	3.4	0.8	4.954	19	<b>0.001</b>
6	49.7	52.7	3	3.8	0.8	3.493	21	<b>0.002</b>
7	51.4	53.6	2.2	4.7	1.0	2.306	21	0.031
8	51.6	55.8	4.2	6.6	1.4	2.732	20	0.013
9	52.4	55.2	2.8	6.0	1.2	2.021	22	0.056
10	55.1	55.7	0.6	6.3	1.4	0.590	20	0.562
11	57.1	58.0	0.9	4.7	1.0	0.539	21	0.596
12	57.1	61.0	3.9	8.2	1.7	2.027	21	0.056
13	60.4	63.8	3.4	9.8	2.2	1.604	19	0.125
14	62.1	62.1	0	6.5	1.4	0.385	20	0.705
15	62.9	64.7	1.8	7.2	1.6	1.143	19	0.267
16	66.6	65.1	-1.5	6.9	1.5	-0.989	19	0.335
17	68.6	68.4	-0.2	7.4	1.7	0.060	19	0.953
18	68.8	66.3	-2.5	7.4	1.7	-1.630	19	0.119

It is apparent from the Table 1 that there is no difference in mean body mass of boys and girls of 5 years of age. During 6 to 13 years of age, the girls become heavier than boys; but, the difference is insignificant ( $t < 1.0$  and  $p > 0.05$ ), after 13 years of age, the trend was reversed and boys become heavier than the girls, during 13 to 15 years the difference is insignificant, but at 16 years of age and onward this difference is significant ( $t = -2.0$  to  $-0.5$  and  $p < 0.05$ ). In this way, finally, the boys become heavier than the girls, as also clear from *t-test* and error bar diagramme (Figure 1).

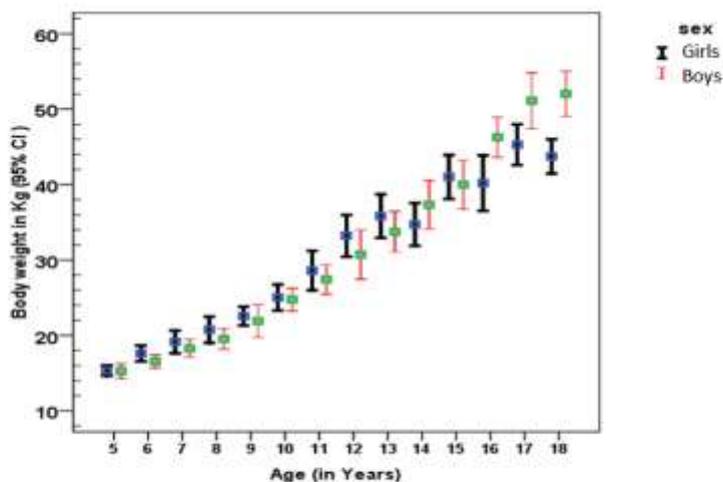
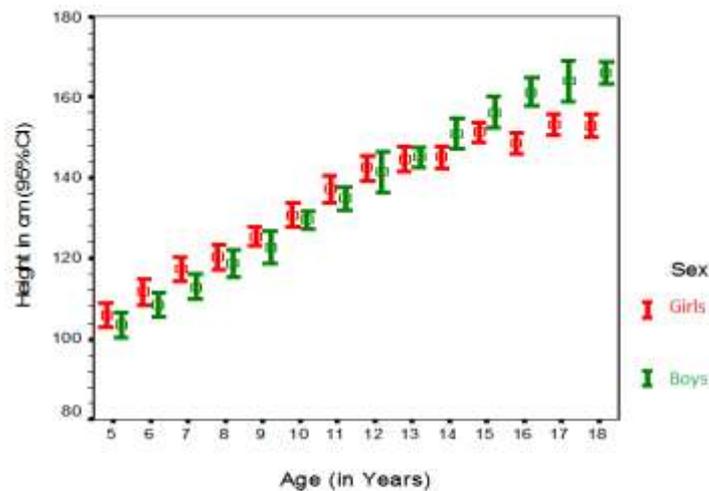


Figure 1. Age wise comparison of Body weight

It is evident that girls are taller than the boys of upto 12 years of age but difference is insignificant ( $t < 1.0$  and  $p > 0.05$ ). After 13 years of age, boys exceed the girls and become taller and the difference was found significant which is also apparent from *t-test* and illustrated through error bar diagramme (Figure 2).



**Figure 2. Age wise comparison of height**

Sitting height is a length of trunk, neck and head. But primarily it gives information about trunk size of an individual which is largely determined by heredity. In the present study the growth pattern of sitting height of girls and boys were compared. It was found that girls are taller than boys up to 13 year of age; there is insignificant difference in their sitting height during 5-15 years, but after 15 years, the difference was significant, which is further proved by *t-test* and error bar diagramme (Figure 3). The boys were significantly taller in sitting height, after 15 years of age.

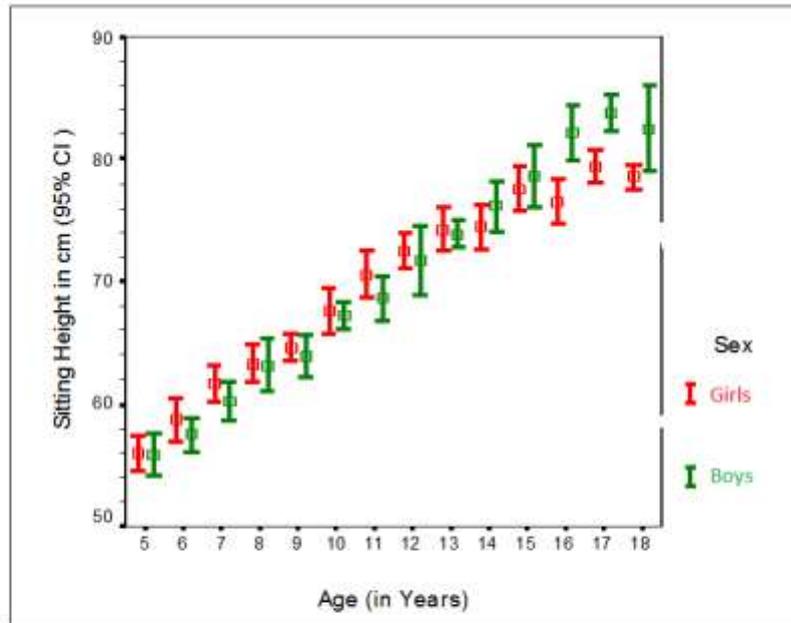


Figure 3. Age wise comparison of sitting height

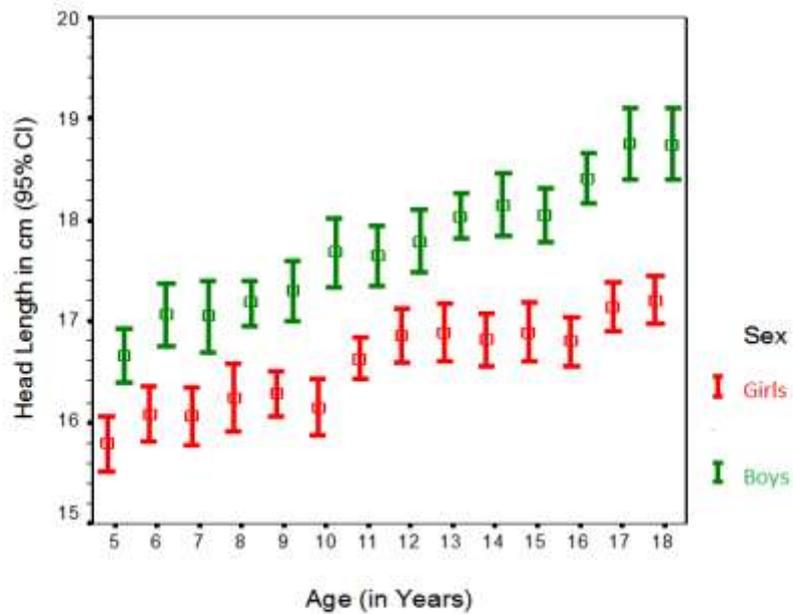
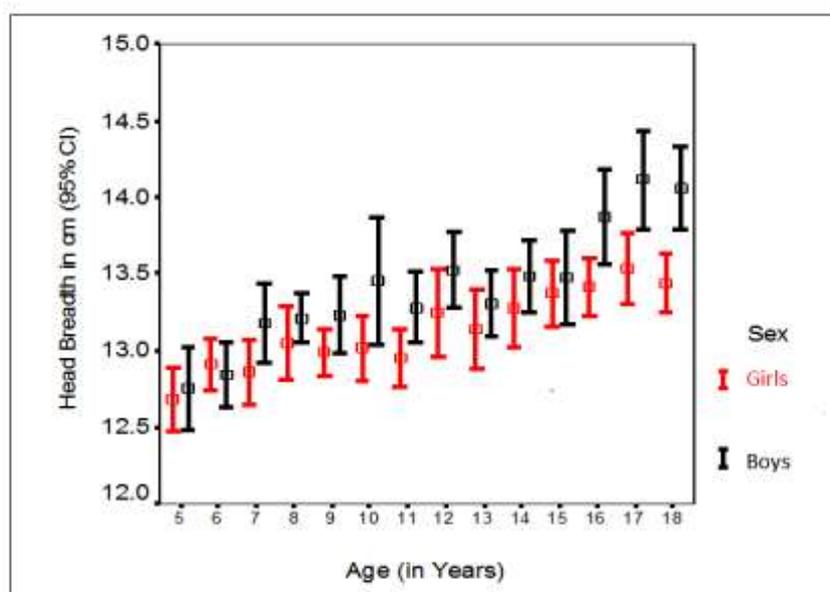


Figure 4. Age wise comparison of head length

It was found that the boys have longer and broader head than girls. The difference of head length is statistically significant ( $p > 0.001$ ) and also apparent from error bar diagramme (Figure 4); whereas the difference of head breadth was insignificant for age cohort 5- 15 years; but after 15 years of age, there is significant difference in their head breadth, which is also apparent from *t-test* and error bar diagramme (Figure 5).



**Figure 5. Age wise comparison of head breadth**

Alike head length and breadth, the head circumferences of girls' were smaller than boys except 9, 12, 13 and 15 years of age; although this difference is insignificant ( $t < 1.0$  and  $p > 0.05$ ). Head circumference of boys and girls is similar for 10 years of age. After 16 years of age, the difference was found significant as also evident from *t-test* and error bar diagramme (Figure 6).

The mean chest circumference of girls is larger than boys between 5 to 15 years of age, but after 15 years of age, the chest circumference of boys become larger than girls, although the difference is insignificant throughout (Figure 7).

It was found that girls' upper arm was thicker than boys up to 15 years of age; whereas, after 16 years, boys' upper arm was thicker, although this difference was insignificant ( $t < 1.0$  and  $p > 0.05$ ), the age 9 and 18 years are exception (Figure 8), in which the difference was significant.

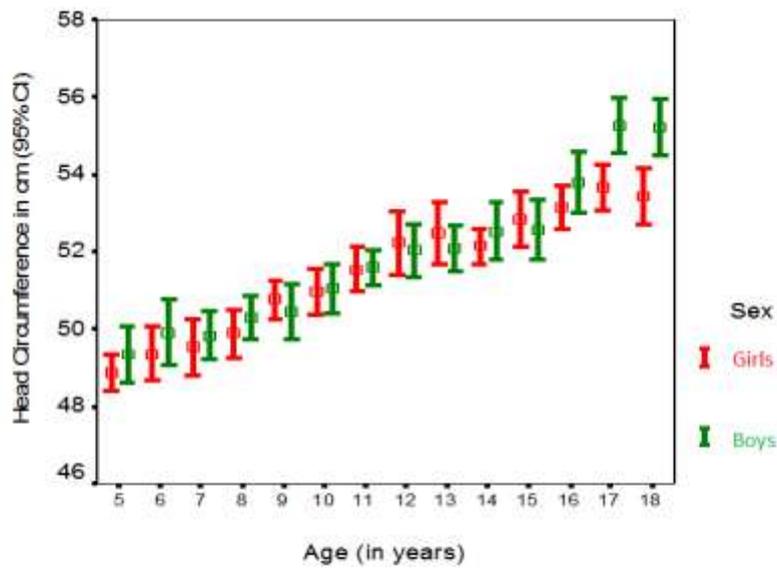


Figure 6. Age wise comparison of head circumference

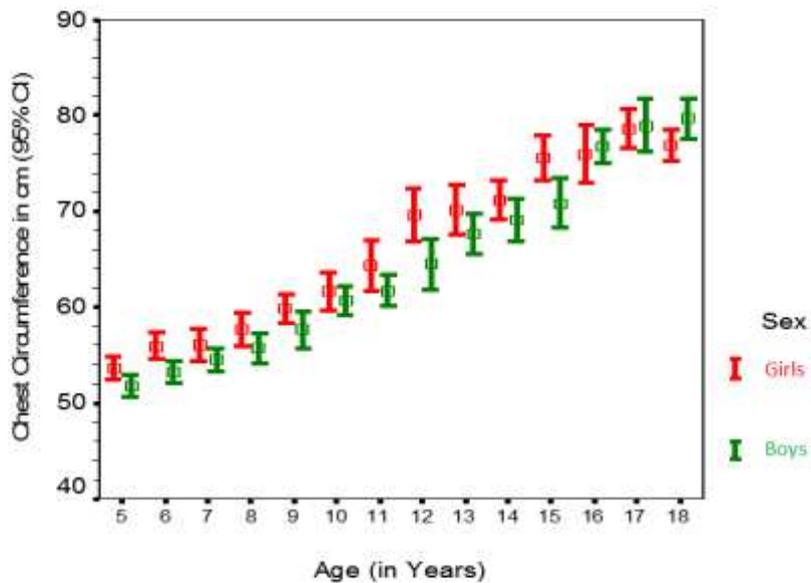
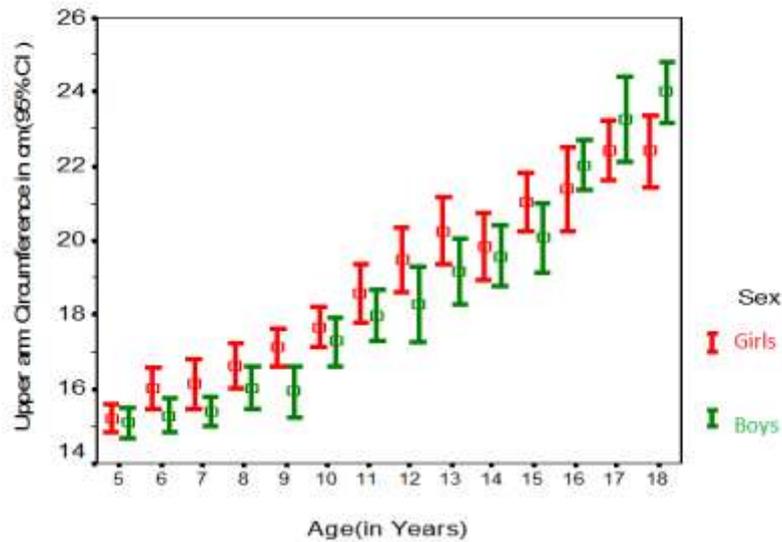
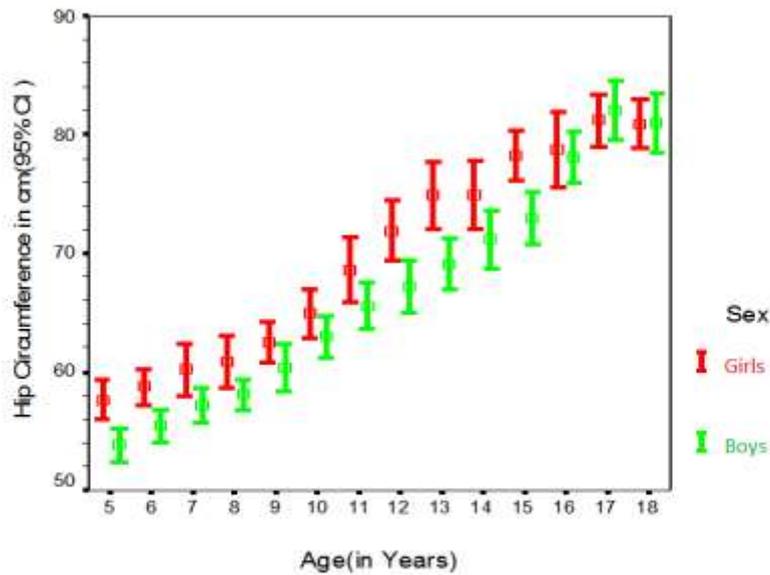


Figure 7. Age wise comparison of chest circumference

Girls' hip are thicker than boys during childhood and adolescence upto 15 years of age and the difference is significant with an exception of 9, 10 and 11 years of age. From the age of 16 years and onward the boys hip circumference become almost equal to the girls with minute difference as also evident from error bar diagramme (Figure 9).



**Figure 8. Age wise comparison upper arm circumference (in cm)**



**Figure 9. Age wise comparison of hip circumference**

Alike hip circumference, the waist circumference of girls' was also broader as compared to boys of upto 13 years of age, whereas at 14 years of age, the mean of waist circumference of boys and girls is equal (62.1cm). After 15 years of age, boys' waist is broader than girls. There is significant difference in mean waist circumference of boys and girls of 5-9 years of age; but after 10 years there is insignificant difference in their waist circumference (figure10).

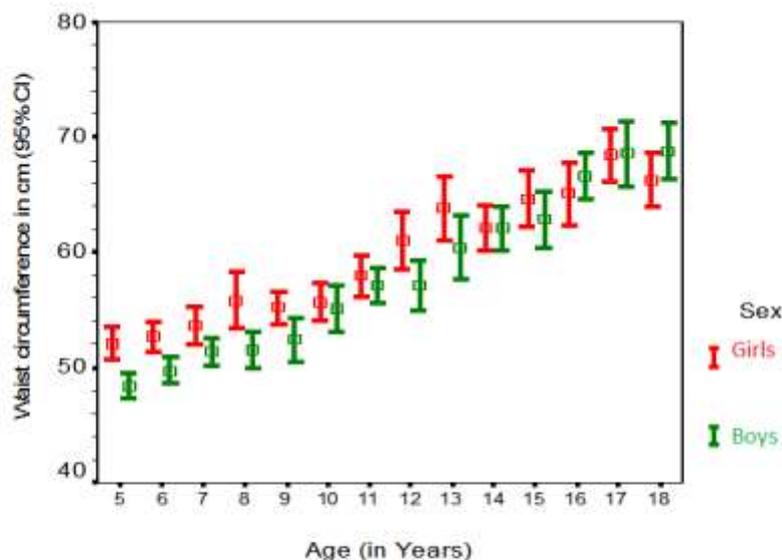


Figure 10. Age wise comparison of waist circumference

Table 2. Regression coefficient and F-statistics of age (independent variable) and different anthropometric characteristics among school going girls and boys.								
S. No	Dependent Variables	Coefficients of regression					F-statistics	
		R	R <sup>2</sup>	$\beta$	SE	t Value	F Change	P Value
Pre-pubertal Girls (Age<11 Years age)								
1	Height	0.778	0.605	4.803	0.335	14.33	205.24	0.001
2	Sitting height	0.725	0.526	2.195	0.18	12.18	148.41	0.001
3	Weight	0.708	0.502	0.272	0.023	11.62	134.98	0.001
4	Chest circumference	0.577	0.333	1.514	0.185	8.19	67.04	0.001
5	Hip circumference	0.480	0.230	1.379	0.218	6.33	40.08	0.001
6	Upper arm circumference	0.523	0.273	0.456	0.064	7.10	50.37	0.001
7	Waist circumference	0.339	0.115	0.789	0.189	4.18	17.43	0.001
8	Head circumference	0.466	0.218	0.434	0.071	6.10	37.25	0.001
9	Head length	0.195	0.038	0.074	0.032	2.30	5.28	0.023
10	Head Breadth	0.211	0.045	0.058	0.023	2.50	6.26	0.014
Pubertal and Post-Pubertal Girls (Age $\geq$ 11 Years age)								
1.	Height	0.606	0.367	2.189	0.218	10.05	100.94	0.001
2.	Sitting height	0.608	0.369	1.210	0.120	10.09	101.79	0.001

3.	Weight	0.626	0.392	0.176	0.017	10.60	112.34	0.001
4.	Chest circumference	0.611	0.373	1.845	0.181	10.18	103.67	0.001
5.	Hip circumference	0.579	0.335	1.768	0.189	9.37	87.75	0.001
6.	Upper arm circumference	0.544	0.295	0.553	0.065	8.54	72.97	0.001
7.	Waist circumference	0.467	0.218	1.228	0.176	6.97	48.53	0.001
8.	Head circumference	0.401	0.160	0.279	0.048	5.77	33.25	0.001
9.	Head length	0.256	0.066	0.064	0.018	3.50	12.21	0.001
10.	Head Breadth	0.299	0.090	0.069	0.017	4.14	17.14	0.001
		Pre-pubertal Boys (Age<12 Years age)						
1.	Height	0.772	0.597	5.143	0.368	13.97	195.17	0.001
2.	Sitting height	0.717	0.514	2.260	0.191	11.82	139.71	0.001
3.	Weight	0.694	0.484	0.259	0.023	11.08	122.83	0.001
4.	Chest circumference	0.654	0.427	1.685	0.170	9.93	98.51	0.001
5.	Hip circumference	0.642	0.412	1.762	0.183	9.61	92.34	0.001
6.	Upper arm circumference	0.460	0.212	0.391	0.066	5.96	35.47	0.001
7.	Waist circumference	0.502	0.252	1.198	0.180	6.66	44.39	0.001
8.	Head circumference	0.313	0.098	0.301	0.080	3.78	14.31	0.001
9.	Head length	0.386	0.149	0.169	0.035	4.81	23.14	0.001
10.	Head Breadth	0.345	0.119	0.134	0.032	4.22	17.79	0.001
		Pubertal and Post-Pubertal Boys (Age≥12 Years age)						
1.	Height	0.787	0.619	4.581	0.280	16.34	266.94	0.001
2.	Sitting height	0.714	0.510	2.209	0.169	13.07	170.70	0.001
3.	Weight	0.799	0.639	0.171	0.010	17.03	289.92	0.001
4.	Chest circumference	0.788	0.620	2.700	0.165	16.37	267.89	0.001
5.	Hip circumference	0.760	0.577	2.511	0.168	14.96	223.88	0.001
6.	Upper arm circumference	0.731	0.534	0.902	0.066	13.72	188.14	0.001

7.	Waist circumference	0.659	0.434	1.882	0.168	11.22	125.89	0.001
8.	Head circumference	0.636	0.405	0.553	0.052	10.56	111.42	0.001
9.	Head length	0.496	0.246	0.161	0.022	7.32	53.56	0.001
10.	Head Breadth	0.422	0.178	0.119	0.020	5.96	35.54	0.001

To understand, the sexual dimorphism in human growth during pre-puberty and puberty+post-puberty regression analysis were computed. The age of samples were taken as independent variable, whereas above stated ten anthropometric characteristics viz. body weight, height etc. were taken as dependent variable. The findings of regression analysis are presented in Table 2. The regression coefficient was found significant ( $p > 0.001$ ) for all the 10 measurements. During pre-puberty, it was found that the growth pattern of height, body weight sitting height, upper arm circumference and head circumference was faster among girls as compared to boys; whereas, the growth pattern of head length, head breadth and circumferences like chest, waist and hip circumference were faster among the boys (Figure 11). Further during pre-puberty the regression coefficient is highest ( $r^2 = 0.605$ ) for stature (height) of girls and lowest ( $r^2 = 0.038$ ) for head length. It can be inferred that among girls 60.5% of height and 3.8% of head length was determined by age during pre-puberty. The remaining values are in-between the two. At the same time, during puberty and after puberty the growth of all above body dimension and mass is faster among boys as compared to girls. The regression coefficient ( $r^2$ ) of height for boys is 0.619 as compared to 0.367 for girls. Weight gain and expansion of chest circumference is further faster among boys ( $r^2 = 0.639$  and 0.620) respectively (Figure 12). In this way, at adulthood boys become taller and heavier as compared to girls.

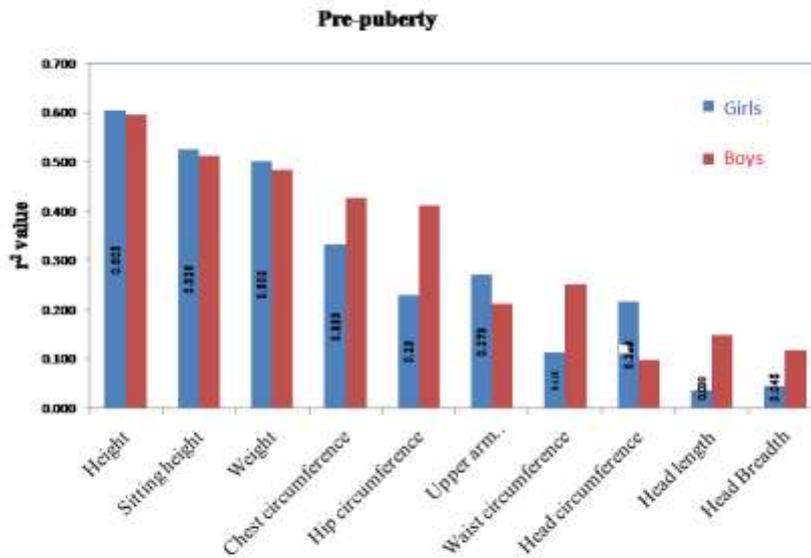


Figure 11. Bar diagram of regression coefficient ( $r^2$ ) of age on different body dimensions among boys and girls during pre-pubertal life.

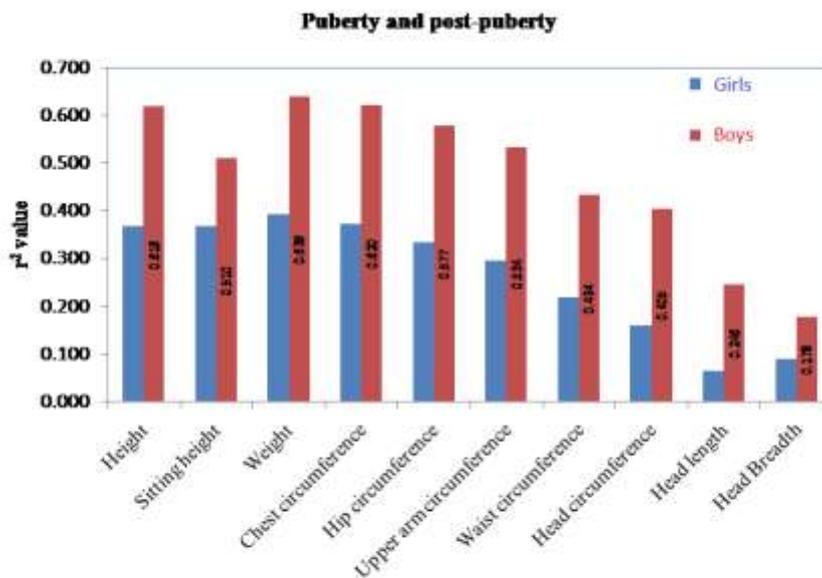


Figure 12. Bar diagram of regression coefficient ( $r^2$ ) of age on different body dimensions among boys and girls during pubertal and post-pubertal life.

## Discussion

The findings of this study are based on the comparison of different anthropometric measurements. Girls' were found better in body weight, height, sitting height, head circumference, as compared to boys during early childhood and upto pubertal stage, but after

puberty the boys exceeds to girls in all body dimension considered for present study. It should be noted that head length and head breadth of boys were thoroughly larger than the girls. At around 10 years of age, puberty started, but there isn't much difference in the growth rate between two sexes. Growth rates changed during puberty, when hormones started the process of physical changes in teens, which occur at different individual rates and at different ages within their sex group. Growth continues for one or two years during puberty, but boys and girls develop at different rates.

The onset of puberty in girls starts at around the age of 10. Girls on the average start their growth spurt between the ages of 10 to 14 years, about a year before boys. This is the reason that girls are often taller than boys of the same age during early childhood. The growth spurt in girls is also shorter than boys. Before girls start menstruating they have already reached close to their maximum height.

The average boy starts his growth spurt at the age of 12 years. Boys grow 3-7 cm per year, but the most intense period of growth lasts in a few months. At the end of puberty, boys are usually about 13 cm taller than girls on the average. The peak of growth is generally two years after puberty begins.

Differences in human body size and body proportions within populations are well known for various age groups. But there is little information about difference in growth pattern of boys and girls specifically during pre-puberty, puberty and post-pubertal span of life. Sexual dimorphism in human populations is relatively small as compared to non-human primates (Guegan et al. 2000). Present findings on significant increase of difference of anthropometric parameters at puberty in boys and girls support this hypothesis. There is a high correlation between sex hormones and the sex-specific development of the physique.

Different approaches have been undertaken to analyze sexual dimorphism. Some more or less sophisticated indices like the index of androgyny were developed to quantify anthropometric differences between the two sexes (Knussmann 1988).

In almost all Indian populations, boys have a better access to food and basic amenities than girls (Kishor 1993). Numerous studies have also reported discriminations in diet and basic amenities against the girls (Borooah 2004, Thakur and Gautam 2014 & 2015). Still, the girls were found comparatively taller and heavier during early or pre-pubertal life. But, after

puberty the scenario is reversed; clearly indicates that there is sexual dimorphism in human growth.

. The studies on Croatian and several other European populations pointed out that during pre-puberty, until the age of 8 to 9 years, sexual dimorphism in stature and sitting height is negligible. This pattern was noted in the Harpenden study (Tanner1986), Similar findings were reported in other European studies, e.g. Slovenian (Tomzo- ravnik 1986), German (Georgi et al, 1996), Spanish (De La et al. 1997), Hungarian (Eiben et al. 1991) etc. During puberty, sexual dimorphism in stature and sitting height markedly differs among populations due to the variation in timing and intensity of the morphological changes. In late adolescence, when linear growth is almost completed, there is again a considerable inter population similarity in sexual dimorphism despite the fact that its extent is maximal during this period.

Throughout the pre-pubertal growth period girls achieved larger amounts of final linear size for age which suggests their earlier bone maturation. This was also documented by the Zürich Study (Gasser et al. 1991).

The differential growth dynamics of body segments greatly influences changes of body proportions. Legs and stature have similar patterns of growth, especially in the pre-pubertal period in both sexes stressing stronger dependence of stature on leg length than on sitting height or growth of trunk, which is also reported on the basis of correlation and regression analysis on adult population by Adak et al. (2006), Gautam (2007), Gautam and Thakur (2009) and others. The trend was associated with better nutritional and health status. It exists in both sexes and confirms that environmental factors influence body shape as well as body size, significantly.

Finally, the present findings corroborate the sexual dimorphism in human growth and development. During early or pre-pubertal life the girls have faster growth as compared to boys of same age, but after puberty, the boys exceed the girls and become taller and heavier.

## **Conclusion**

It can be concluded that there is no sexual dimorphism in humans during early stage of life or pre-pubertal span of life; but with onset of puberty, the boys not only, become significantly taller and heavier than girls; but in other body dimensions too, they grow larger

and faster as compared to girls. This change in growth rate occurs during puberty, because hormones start the process of physical changes, which occur at different individual rates and at different ages within their sex group. Finally, the boys become distinctly larger, heavier and taller and sexual dimorphism is apparent.

### **Acknowledgement**

The Authors are grateful to all the children participated in the study and their parents for cooperation during data collection. They expressed their deep gratitude to the district authorities and Principle, Head Masters/Mistress and teachers of schools who have given their consent and provided basic facility during data collection, without their permission, it was not possible at all. Authors are also thankful to Prof. A.N. Sharma, the Head, Department of Anthropology, Dr. H.S. Gour University, Sagar, MP, India for facilitating through laboratories and equipment; and the faculty members for their help and cooperation during the study.

### **Contribution of Authors:**

The idea and vision behind the theme of paper was given by RKG, who has pivotal role in analysis and presentation of data. He trained RT for field work and data collection. He thoroughly edited and revised the paper before and after review. RT has executed the task; she obtained consent and collected data. She did analysis in the supervision of RKG. She prepared first draft of the paper and assisted RKG in revision of the manuscript. In this way, both authors were involved in data collection, analysis and drafting the manuscript and approved the final manuscript.

**Conflict of Interest:** The Author declares that there is no conflict of interest.

### **Reference**

- Adak DK, Gautam RK, Bharati S, Gharami A, Pal M & Bharati P. 2006. Body mass index and chronic energy deficiency of adult males of central Indian populations. *Human biology*, 78(2): 161-178.
- Bailey KV & Ferro-luzzi A. 1995. Use of body mass index of adults in assessing individual and community nutritional status. *Bull World Health Organ* 73:673–680.
- Bisai S, Bose K & Ghosh A. 2008. Nutritional status of Lodha children in a village of Paschim Medinipur district, West Bengal. *Indian J Public Health* 52:203-6.

- Bogin B, Kappel M, Verela MI, Silva, Orden AB, Smith PK & Loucky J. 2001. How genetic are human body proportions? In: Dasgupta PR, Hauspie (Eds.): Perspectives in human growth, development and maturation. (Kluwer Academic Publishers, Dordrecht).
- Bogin, B. 1988. Patterns of human growth. (Cambridge University Press, Cambridge.)
- Borooh VK. (2004): Gender bias among children in India in their diet and immunization against disease. SocSci Med 58:1719–1731.
- Bose K, Bisai S, Chakraborty J, Datta N & Banerjee P. 2008. Extreme levels of underweight and stunting among preadolescent children of low socioeconomic class from Madhyamgram and Barasat, West Bengal, India. Coll Antropol 32:73–77.
- Chodhury SD, Chakraborty T & Ghosh T. 2008. Prevalence of undernutrition in Santal children of Puruliya district, West Bengal. Indian Pediatr 45:43–46.
- De la Puente ML, Canela J, Alvarez J, Salleras L & Vicens-Calvet E. 1997. Cross-sectional growth study of the child and adolescent population of Catalonia (Spain). Ann. Hum. Biol., 24, 435.
- Deurenberg-Yap M, Schmidt G, Van Staveren WA & Deurenberg P. 2000. The paradox of low body mass index and high body fat percentage among Chinese, Malays and Indians in Singapore. Int J Obes Relat Metab Disord 24:1011–1017.
- Eiben OG, Barabas A & Panto E. 1991. The Hungarian National Growth Study I: Reference data on biological developmental status and physical fitness of 3 –18 year-old Hungarian youth in the 1980s. (Humanbiologia Budapestiensis, Budapest,).
- Ellison PT. 1982. Hum. Biol. 54 629. Cited from Zivicnjak M, Narancic NS, Szivoczal L, Franke D, Hrenovic J, Bisof V. 2003. Gender-Specific Growth Patterns for Stature, Sitting Height and Limbs Length in Croatian Children and Youth (3 to 18 Years of Age), Coll. Antropol. 27 1: 321–334 UDC 572.512:612.65-055 Original scientific paper
- Gasser T, Keip A, Ziegler P, Largo R, Molinari L & Prader A. 1991. Ann. Hum. Biol., 18, 449. Cited from Zivicnjak M, Narancic NS, Szivoczal L, Franke D, Hrenovic J, Bisof V. 2003. Gender-Specific Growth Patterns for Stature, Sitting Height and Limbs Length in Croatian Children and Youth (3 to 18 Years of Age), Coll. Antropol. 27 1: 321–334 UDC 572.512:612.65-055
- Gautam R. 2007. Physical Growth and Body Composition among two female populations of Central India— Baiga (Primitive Tribe) and Brahmin. In Contemporary Studies in Anthropometry (Ed.) A.N. Sharma, Sarup and Sons, New Delhi. p 139-147 (2007).

- Gautam RK, Adak DK, Gharami AK & Datta T. 2006. Body Mass Index in Central India: Inter District Variation. *Anthropologischer Anzeiger* : 64, 4, 447-461.
- Gautam RK, Adak DK, Pal M & Bharati P. 2014. Morphometric variation among the Central Indian populations. *Human Biology Review*, 2(2), 153-175.
- Gautam RK, Jhariya J & Kumar P. 2015. Globally Declining Population of Women Folk Causing Sex Imbalance Is a Serious Concern: An Analysis of Sex Ratio around the Globe *Journal of Anthropology* Vol. 2015, Article ID 431458, <http://dx.doi.org/10.1155/2015/431458>
- Ge X, Natsuaki MN, Neiderhiser JM & Reiss D. 2007. "Genetic and Environmental Influences on Pubertal Timing: Results From Two National Sibling Studies". *Journal of Research on Adolescence* 17: 767. [doi:10.1111/j.1532-7795.2007.00546.x](https://doi.org/10.1111/j.1532-7795.2007.00546.x).
- Gergi M, Schaefer F, Wuhl E & Scharer K. 1991. *Monatsschr. Kinderheilkund.*, 144, 813. Cited from Zivicnjak M, Narancic NS, Szivovicza1 L, Franke D, Hrenovic J, Bisof V. 2003. Gender-Specific Growth Patterns for Stature, Sitting Height and Limbs Length in Croatian Children and Youth (3 to 18 Years of Age), *Coll. Antropol.* 27 1: 321–334 UDC 572.512:612.65-055 Original scientific paper
- Gibson RS. 1990. *Principal of Nutritional Assessment* (New York: Oxford University Press).
- Gorstein J, Sullivan K, Yip R, de Onís M, Trowbridge F, Fajans P & Clugston G. (1994): Issues in the assessment of nutritional status using anthropometry. *Bull World Health Organ* 72:273–283
- Greil H. 2006. Patterns of Sexual Dimorphism from Birth to Senescence *Coll. Antropol.* 30. 3: 637–641.
- Guegan JF, Teriokhin AT & Thomas F. 2000. Human fertility variation, size-related obstetrical performance and the evolution of sexual stature dimorphism. *Proc R Soc Lond Ser B Biol Sci* 267: 2529–2535
- Hamieda J & Billot L. 2002. Nutritional status of Libyan children in 2000 compared with 1979. *East Mediterr Health J* 8:1–10.
- Khongdier R. 2002. Body mass index and morbidity in adult males of the War Khasi in Northeast India. *Eur J Clin Nutr* 56:484–489.
- Kishor S. 1993. May God give sons to all: Gender and child mortality in India. *Am Sociol Rev* 58:247–265.

- Knussmann R. 1988. Somatometrie. In: KNUSSMANN, R. (Ed.): Anthropologie. Handbuch der vergleichenden Biologie des Menschen. Vol.1/1 Anthropometrie. (Gustav Fischer Verlag, Stuttgart – Jena – New York,)
- Mehta P & Shringapure B. 2000. Diet nutrition and health profile of elderly population of urban Baroda. *Indian J Public Health* 44:24–28.
- Misra A, Sharma R, Pandey RM & Khanna N. 2001. Adverse profile of dietary nutrients, anthropometry and lipids in urban slum dwellers of northern India. *Eur J Clin Nutr* 55:727–734.
- Mustanski BS, Viken RJ, Kaprio J, Pulkkinen L & Rose RJ. 2004. "Genetic and environmental influences on pubertal development: longitudinal data from Finnish twins at ages 11 and 14." *Developmental psychology* 40 (6): 1188–1198.
- Olivier F, Semproli S, Pettener D & TOSELLI S. 2008. Growth and malnutrition of rural Zimbabwean children (6–17 years of age). *Am J Phys Anthropol* 136:214–222.
- Papalia DE & Wendkos S. Olds. (1989) Human development. (McGraw-Hill, Baskerville,).
- Rao KM, Laxmaiah A, Venkaiah K & Brahman GN. 2006. Diet and nutritional status of adolescent tribal population in nine states of India. *Asia Pac J Clin Nutr* 15:64–71.
- Semproli S & Gualdi-Russo E. 2007. Childhood malnutrition and growth in a rural area of Western Kenya. *Am J Phys Anthropol* 132:463–469.
- Sharma JC. (1970): Physical growth and development of the Maharashtrians. (Ethnographic and Folk Culture Society, Lucknow.
- Sharma V & Sharma A. 1992. Health profile of pregnant adolescents among selected tribal populations in Rajasthan, India. *J Adolesc Health* 13:696–699.
- Tanner JM, Hayashi T, Preece MA & Cameron N. 1982. Increase in length of leg relative to trunk in Japanese children and adults from 1957 to 1977: Comparison with British and with Japanese Americans. *Ann. Hum. Biol.* 9:411-423
- Tanner JM, Whitehouse RH, Marubini E & Resele LF. 1976. The adolescent growth spurt of boys and girls of the Harpenden growth study *Ann. Hum. Biol.*, 3 109.
- Tanner JM. 1986. Normal growth and techniques of growth assessment. *Clin. Endocrinol. Metab.*, 15, 411.
- Thakur R & Gautam RK. 2015a. Nutritional status among boys and girls of a central Indian Town (Sagar). *Anthropological Review* • Vol. 78 (2), 197–212 (2015).
- Thakur R & Gautam RK. 2014. Prevalence of undernutrition among School going boys (5-18 years) of a Central Indian city (Sagar). *Human Biology Review*, 3 (4), 364-383.

- Thakur R, Gautam RK. 2015b. Assessment of nutritional status among girls of 5-18 years of age of a Central Indian City (Sagar), *Human Biology Review*, 4 (4), 325-336.
- Thakur R and Gautam RK. 2016. Co-existence of undernutrition and obesity: A cross sectional study among girls and boys below 20 years of age. . *Human Biology Review*, 5 (2), 199-212.
- Tiwari MK, Sharma KKN, Bharati S, Adak DK, Ghosh R & Bharati P. 2007. Growth and Nutritional Status of the Bharia – A Primitive Tribe of Madhya Pradesh, *Coll. Antropol.* 31 1: 95–101
- Tomazo-Ravnik, T. 1986. Growth standards of Ljubljana school children *Antrop. Közl.*, 30, 39.
- Treloar SA & Martin NG. 1990. "Age at menarche as a fitness trait: nonadditive genetic variance detected in a large twin sample."*American Journal of Human Genetics* 47 (1): 137–148.PMC 1683767. PMID 2349942.
- Zerfu M & Mekasha A. 2006. Anthropometric assessment of school age children in Addis Ababa, *Ethiop Med J* 44:347–352.
- Zivicnjak M, Narancic NS, Szivoczai L, Franke D, Hrenovic J & Bisof V. 2003. Gender-Specific Growth Patterns for Stature, Sitting Height and Limbs Length in Croatian Children and Youth (3 to 18 Years of Age), *Coll. Antropol.* 27 1: 321–334 UDC 572.512:612.65-055.