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Secular trends in physical growth and maturation in 7 to 21 year-old Bengali boys and girls from Kolkata, India, over six decades of time interval

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In the backdrop of ongoing socioeconomic transition in India, a cross-sectional growth and socioeconomic survey was undertaken in the families of 4194 Bengali children, adolescents and youth of both sexes aged 7.0 to 21.0 years from Kolkata city, India during 1999-2011.The objective of the study was to investigate secular trends phenomena in the measures of physical growth and maturation of three linear and two width measures (standing height, sitting height, subischial leg length, biacromial and bi-iliocristal diameters) through comparisons of results of the present study with two earlier growth studies (1952-66 and 1982-83) carried out in the same population during the pre-transitional period of the country (before 1990s). The possible influences of socioeconomic, demographic and public health related factors have also been investigated. Approximately over six decades of time difference, mean values of anthropometric measures increased in both sexes and that was more evident during adolescent years than at maturity. In standing height, the highest increase of mean value was 14.4 cm for boys at 13.0 years and 11.8 cm for girls at 10.0 and 11.0 years of age. In adulthood, averages of four body dimensions (except bi-iliocristal diameter) increased in a lesser magnitude than the increase found during adolescent years. Mean of adult standing height in males increased by 3.0 cm of which increase in mean of subischial leg length was greater (1.8 cm) than the increment in mean sitting height (1.2 cm). Increased standard deviation values over time indicated early initiation of adolescent growth spurt of the contemporary children. Time of reaching peak of the spurt estimated by fitting Preece-Baines model 1, was found to be about two years ahead as recorded in the contemporary population compared to the children of earlier study periods. Finally, mean age at menarche (11.80 years) of the contemporary Kolkata girls was observed to have declined by 1.10 years over about four decades of time span.

Among the probable factors responsible for positive secular trends, came into the discussion, were improvements in several socioeconomic factors including maternal education level, monthly family expenditure per capita and decline in sibship size of the families. In addition, improvements in several important parameters of public health, namely decline in infant mortality and morbidity rates, increase in life expectancy, child immunization rate and overall Human Development Index of Kolkata population appeared to be the secondary contributing factors for the observed trends.

Key words: *Adolescent growth spurt, standing height, sitting height, subischial leg length, biacromial diameter, bi-iliocristal diameter, secular trends.*

Introduction

India implemented the programme of Economic Globalization during the early nineties and since then over last two decades, the people of the country had been experiencing a rapid transition in the socioeconomic, epidemiological, nutritional and demographic spheres (Mini, 2009). Socioeconomic transition in a country should be considered as the main transitional process responsible for the emergence of other related processes in life (Hermanussen, 2013). A study explained the inter-relationship between the transitional processes in projecting the public health profile in India during the era of Economic Globalization (Shetty, 2002). The important features of socioeconomic transition in the country were manifested in various ways. To cite a few, an increase in India's Gross National Product (GNP) from INR 5,034 billion (229,339,425 USD) in 1990-1991 to INR 42,970 billion (963,885,150 USD) in 2007-2008 has been noticed (Government of India, 2011). India's real Gross Domestic Product (GDP) at current prices has moved up from INR 6,383 (290.80 USD) in 1990-91 to INR 33,283 (746.59 USD) in 2007-08. A decline in the number of people living below poverty level was observed in association with the escalated inequality between rural and urban people in the sphere of health services and infant mortality (Gopalan, 1998; Thankappan, 2001).

The process of socioeconomic transition that has resulted due to economic development of the respective countries was congenial for initiating growth and nutrition related studies in children. In the transitional phase, secular trends phenomena in growth and nutrition in children and adolescents were observed and had been interpreted as the product of continuous and often additive interactions between genes and the changing socioeconomic environments (Ji & Chen, 2008; Thomis & Towne, 2006). As a consequence, in last few decades, auxologists, nutritionists and public health specialists from different countries of Asia, Africa, Europe, and Latin America have persuaded a large number of growth and nutrition related studies focusing two important issues, namely, monitoring of secular trends phenomena and measuring socioeconomic gradients. China and Brazil, being two leading countries in such transition, have undertaken prolific number of growth studies (Kac, 1998; Franca Junior et al., 2000; Monteiro & Conde, 2000; Ji & Chen, 2008; Zhang & Wang, 2009; Vargas et al., 2010; Farias et al., 2012). In India, auxological investigations focussing secular trends and social gradients are still small in number in relation to the size of the country and its population. It may be noted that these two issues were principally focused by the auxologists during the time of rapid industrialisation and urbanisation in Europe, America, and Japan (Tanner, 1981; Bielicki, 1986).

Studies on secular trends of pubertal maturation are important for a population and that require standard reference data for comparison. Studies on secular trend of pubertal maturation are reported from some transitional countries including India (Bagga & Kulkarni, 2000). In India, during the pre-transition period of the country (before 1990s) many growth studies have been carried out among infants, children, adolescents, and young adults with varied sample size, representing different ethnic and linguistic groups and people living in unequal socioeconomic situations. Results of these studies would be extremely useful as baseline information for observing the amount of secular changes noticed in different growth variables by comparing with the results of growth studies launched during the period of transition. Not only the measures of height and weight, but different body segments, measures of body shape, body composition, physical and pubertal maturation, nutritional status etc. may be evaluated to demonstrate the time trends. In the present communication, therefore, an attempt has been made to examine the secular trends phenomena in overall body size, body segments and in adolescent growth spurt of five anthropometric traits (standing height, sitting height, subischial leg length, biacromial and bi-iliocristal diameters) in the urban Bengali Hindu population from Kolkata, West Bengal, India. Three growth studies were compared of which two were carried out during the pre-transition period of the country (during 1952 -1966 and 1982-83) and the present study, during the period of ongoing transition (1999-2011).

Participants and Methods

The Bengali population is an ethno-linguistic group, native to the historic region of West Bengal and Bangladesh. People speak in Bengali which is an Indo-Aryan language of the East Indian Subcontinent and are mostly concentrated in India and Bangladesh. The important features of the comparing three growth studies may be summarized as follows:

The first growth survey, a family-based mixed-longitudinal growth survey was known as Sarsuna-Barisha Growth Study (SBG) that was carried out during 1952 to 1966 (Pre-transition period) among Bengali boys and girls from Kolkata (Hauspie et al., 1980; Das, 1985). Measurements at all occasions were taken by S. R. Das on birth dates or half birth dates of the siblings and measurements were recorded following standard techniques (Martin, 1928). A total number of 3220 participants (1782 boys and 1438 girls) aged 6.0 months to 21.0 years were measured in that survey. The data had been treated as cross-sectional to compare with the data from two successive growth studies. The second growth survey, cross-sectional in nature was carried out only among 825 Bengali boys aged 7.0 to 16.0 years from Kolkata city, during 1982-83 (Pre-transition period) and was named as Kolkata Growth Study 1 (KG 1) (Pakrasi et al., 1988; Dasgupta & Das, 1997). The participants were measured on and around their birth dates (±3 days), following the protocol of International Biological Programme (IBP, 1969). Details of the study were already reported earlier (Dasgupta, 1989; Dasgupta & Das, 1997; de Onis et al., 2001). The third cross-sectional growth survey was carried out in Bengali Hindu population aged 7.0 to 21.0 years between the years 1999-2011 (during transition period) and has been termed by Kolkata Growth Study 2 (KG 2) (Dasgupta, 2015). For boys, the survey was carried out from 1999 to 2011 while for girls, the time span was between 2005 and 2011. For boys, data sets were available from all three growth surveys, and accordingly it was possible to observe the secular trends between the time intervals of three study periods (i.e. between SBG to KG 1, KG 1 to KG 2 and SBG to KG 2). On the other hand, for girls due to the availability of data from two growth studies, secular trends have been observed between two phases (SBG and KG 2). The sample size of the present study (KG 2) was 4194 children, adolescents and youth aged 7.0 to 21.0 years: 1999 boys and 2195 girls from Kolkata city in West Bengal, India. The sample size by age and sex in three growth studies are presented in Table 1.

TABLE 1. Sample size by age and sex in three growth studies in Kolkata, India.

Age (years)	Sarsuna-Barisha growth study (1952-1966)		Kolkata growth study 1 (1982-1983)	Kolkata growth study 2 (1999-2011)	
	Boys	Girls	Boys	Boys	Girls
7.0	107	115	64	123	155
8.0	133	108	87	125	156
9.0	141	124	97	130	151
10.0	140	126	76	117	161
11.0	146	110	98	124	143
12.0	146	123	97	149	145
13.0	142	118	98	159	140
14.0	139	123	95	137	141
15.0	141	104	76	127	148
16.0	125	99	37	138	135
17.0	120	93	X	143	139
18.0	99	72	X	128	136
19.0	93	55	X	132	146
20.0	81	51	X	135	158
21.0	29	17	X	132	141
Total	1782	1438	825	1999	2195

The anthropometric parameters included standing height (cm), sitting height (cm), subischial leg length (cm), biacromial diameter (cm) and bi-iliocristal diameter (cm); measurements were recorded following the protocol of International Biological Program (IBP, 1969). Subischial leg length was derived by subtracting the value of sitting height from the value of standing height. In three growth studies, the measurements were taken using GPM anthropometer (Siber Hegner & Co., Ltd., Swiss standard) to the nearest 0.1 cm. In the present study (KG2 study), all measurements were taken by the properly trained research scholars of one of the co-authors (PDG), on and around birth dates (±3 days) of the participants in order to maintain age grouping and during the day time to avoid diurnal variation.The date of birth was verified from the authenticated documents (birth certificate, hospital discharge certificate etc.).

All three growth studies were linked by several important attributes which are presented in Table 2. These three surveys were carried out in the predominantly middle-class Bengali Hindu population. The participants voluntarily attended the sessions; they were unmarried and in disease free states during the surveys. Girls had no pregnancy records prior to the surveys. The residential areas of the participants were located within a radius of about 20 km from the centre of the Kolkata city and thereby it has been possible to maintain homogeneity in the physical environment of the participants. These were some of the important common criteria that were usually required to fulfil before comparing the data from three surveys and also for drawing any meaningful conclusion from the analysis of data on secular trends (Lindgren & Cernerud, 1992; Rao et al., 2012).

Socioeconomic data for last two growth studies (KG1 and KG2) were collected by the trained interviewers through household visits. The socioeconomic and demographic data from the families of last two growth surveys constituted 24 and 50 items respectively from which parental education, monthly family expenditure per capita and sibship size of the participants have been considered for the present context. In this communication, secular trends have been demonstrated in the measures of overall body size and body segments and in measures of adolescent growth spurt of five body dimensions of the Bengali boys and girls.

Ethical clearance was obtained from appropriate authority prior to the commencement of research project (mentioned in the acknowledgement section). The current cross-sectional growth survey (KG 2) was carried out in the households of school and college going students (boys and girls), sampled from sixty six academic institutions of Kolkata city. The school authorities were requested to provide with the list of students along with their approvals through the Department of Education of the Government of West Bengal. Verbal as well as written informed consent was also obtained from the parents before recording anthropometric measurements of the participants and their family socioeconomic data.

TABLE 2. Summary of three growth studies in Kolkata, West Bengal, India.

Features	Sarsuna-Barisha growth study	Kolkata growth study 1	Kolkata growth study 2
Sponsor	Anthropological Survey of India	Indian Statistical Institute	Neys-Van Hoogstraten Foundation and Indian Statistical Institute
Year	1952-66	1982-83	1999-2011
Sex	Boys and girls	Boys	Boys and girls
Age groups	6 months-21 years	7-16 years	7-21 years
Sample size	3220 (Boys-1782; Girls-1438)	825	4194 (Boys-1999; Girls-2195)
Type of study	Mixed-longitudinal	Cross-sectional	Cross-sectional
Protocol followed	Martin, 1928	International Biological Programme, 1969	International Biological Programme, 1969
Target date of measurements	Birth day - half birth day	Birth day ± 3 days	Birth day ± 3 days
Number of anthropometric measurements	25	22	21
Dietary data	Not collected	24-hour recall	24-hour recall
Social status	Middle class	Middle class	Middle class
Socioeconomic data	Not collected	24 items	50 items

Data analysis

Age specific mean values, standard deviations (sd) and standard errors (se) of anthropometric parameters in three growth studies for boys (SBG, KG1 and KG2) and two growth studies for girls (SBG and KG2) were calculated and compared to measure the magnitude of secular trends; statistical significance of differences in mean values has been determined by student's t-test.Three biological parameters of adolescent growth spurt, namely, averages of age at peak velocity (year), peak velocity (cm per year) and final or mature size (cm), have been estimated using Preece-Baines model 1 (Preece & Baines, 1978) for standing height, sitting height, subischial leg length, biacromial diameter and bi-iliocristal diameter of three growth studies in boys and two of girls; the results were compared to measure the amount of secular changes. All statistical calculations have been performed using Microsoft ® Excel, SPSS statistical package (version 13.0) and R software. A p-value <0.05 was considered statistically significant.

Results

1. Secular trends in overall body size and body segments

Boys

Standing height

The maximum increment of mean value of standing height in boys between studies SBG and KG 1 was 11.6 cm (13.0 years), between studies KG 1 and KG 2 was 4.4 cm (12.0 years) and between studies SBG and KG 2 was 14.4 cm (13.0 years) (Table 3). In all 10 age cohorts between studies SBG and KG 1, in 9 of 10 age cohorts between studies KG 1 and KG 2 and in all 15 age cohorts between studies SBG and KG 2, the increments in mean values were found to be statistically significant.

Sitting height

Results shows that the maximum increment of mean sitting height in boys between studies SBG and KG 1 was 5.6 cm (13.0 years), between studies KG 1 and KG 2 was 2.0 cm (14.0 years) while between studies SBG and KG 2 it was 7.1cm (14.0 years). In all 10 age cohorts between studies SBG and KG 1, in 8 of 10 age cohorts between studies KG 1 and KG 2 and in all 15 age cohorts between studies SBG and KG 2, the increments in mean values were recorded to be statistically significant (Table 4).

TABLE 3. Changes in mean values of standing height (cm) by age in boys over three study periods.

Age (years)	SBG# (1952-1966)				KG 1# (1982-1983)				KG 2# (1999-2011)				Difference of mean values (cm) between study periods		
	n	Mean	sd	se	n	Mean	sd	se	n	Mean	sd	se	SBG vs KG 1	KG 1 vs KG 2	SBG vs KG 2
7.0	107	111.5	5.3	0.51	63	119.3	6.7	0.84	123	120.6	4.8	0.44	7.8**	1.3	9.1**
8.0	132	116.7	4.9	0.43	87	124.1	5.3	0.57	125	127.1	5.5	0.49	7.4**	3.0**	10.4**
9.0	141	121.7	5.2	0.44	96	128.5	6	0.62	130	132.3	6.6	0.58	6.8**	3.8**	10.6**
10.0	140	126.1	5.2	0.44	75	133.0	5.5	0.64	117	136.6	5.6	0.52	6.9**	3.6**	10.5**
11.0	146	130.4	5.5	0.45	97	138.4	6.9	0.7	124	141.7	7.3	0.66	8.0**	3.3**	11.3**
12.0	146	134.9	5.9	0.49	96	143.1	8.8	0.9	149	147.5	8.3	0.68	8.2**	**4.4****	12.6**
13.0	142	139.9	6.7	0.56	98	151.5	7.9	0.79	159	154.3	7.6	0.61	**11.6****	2.8*	**14.4****
14.0	127	146.9	8.1	0.72	93	157.1	8.6	0.9	137	161.2	6.8	0.58	10.2**	4.1**	14.3**
15.0	132	154.0	8.2	0.71	75	162.4	6.2	0.72	127	164.4	6.6	0.59	8.4**	2.0*	10.4**
16.0	117	159.9	6.8	0.62	36	165.7	5.2	0.87	138	167.7	5.8	0.49	5.8**	2.0*	7.8**
17.0	110	163.1	6.2	0.59	NA	NA	NA	NA	143	167.9	5.9	0.49	NA	NA	4.8**
18.0	95	165.2	5.6	0.57	NA	NA	NA	NA	128	168.8	6.1	0.53	NA	NA	3.6**
19.0	92	166.1	5.6	0.58	NA	NA	NA	NA	132	169.1	6	0.52	NA	NA	3.0**
20.0	80	165.9	5.5	0.61	NA	NA	NA	NA	135	169.8	5.8	0.5	NA	NA	3.9**
21.0	29	166.1	5.9	1.09	NA	NA	NA	NA	132	170.1	6.1	0.53	NA	NA	4.0*

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 1: Kolkata growth study 1; KG 2: Kolkata growth study 2. NA: Not available. Digits in bold font indicate highest values in the particular columns.

TABLE 4. Changes in mean values of sitting height (cm) by age in boys over three study periods.

Age (years)	SBG# (1952-1966)				KG 1# (1982-1983)				KG 2# (1999-2011)				Difference of mean values (cm) between study periods		
	n	Mean	sd	se	n	Mean	sd	se	n	Mean	sd	se	SBG vs KG 1	KG 1 vs KG 2	SBG vs KG 2
7.0	105	60.9	2.4	0.24	59	64.6	3.4	0.44	122	65.1	2.7	0.24	3.7 **	0.5	4.2**
8.0	129	62.9	2.3	0.20	83	66.4	2.6	0.29	119	68.1	2.9	0.27	3.5 **	1.7**	5.2**
9.0	139	64.9	2.5	0.21	93	68.2	3.3	0.35	126	69.7	3.4	0.30	3.3 **	1.5*	4.8**
10.0	134	66.4	2.5	0.22	66	70.0	2.8	0.34	114	71.4	2.7	0.25	3.6 **	1.4**	5.0**
11.0	138	68.2	2.5	0.21	93	71.7	3.5	0.36	123	73.0	3.5	0.32	3.5 **	1.3*	4.8**
12.0	140	70.0	2.6	0.22	94	73.6	4.2	0.43	146	75.4	3.8	0.31	3.6 **	1.8**	5.4**
13.0	138	72.1	3.0	0.26	93	77.7	4.7	0.49	159	78.8	3.9	0.31	**5.6** **	1.1*	6.7**
14.0	128	75.2	3.7	0.33	89	80.3	5.3	0.56	135	82.3	3.7	0.32	5.1 **	**2.0***	**7.1****
15.0	130	78.8	4.2	0.37	70	83.4	4.0	0.48	122	84.6	3.4	0.31	4.6 **	1.2*	5.8**
16.0	112	82.0	3.8	0.36	32	86.0	2.8	0.49	131	86.0	3.3	0.29	4.0 **	0.0	4.0**
17.0	109	84.4	3.3	0.32	NA	NA	NA	NA	123	86.8	3	0.27	NA	NA	2.4**
18.0	92	85.7	2.9	0.3	NA	NA	NA	NA	109	87.5	3.1	0.3	NA	NA	1.8**
19.0	82	86.2	3	0.33	NA	NA	NA	NA	121	88.2	2.8	0.25	NA	NA	2.0**
20.0	71	86.8	2.7	0.33	NA	NA	NA	NA	127	88.3	3.2	0.28	NA	NA	1.5**
21.0	23	87.2	2.4	0.51	NA	NA	NA	NA	120	88.9	3.1	0.28	NA	NA	1.7*

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 1: Kolkata growth study 1; KG 2: Kolkata growth study 2. NA: Not available. Digits in bold font indicate highest values in the particular columns.

Subischial leg length

It was observed that maximum increment in mean value of subischial leg length in boys between the first two comparing studies (SBG study and KG 1 study) was 5.8 cm (13.0 years), between studies KG 1 and KG 2 the respective increased values was 2.4 cm (12.0 year), while between studies SBG and KG 2 the increase was 7.7 cm (13.0 year). In all 10 age cohorts between studies SBG and KG 1 and in 8 of 10 age cohorts between studies KG 1 and KG 2 and in 14 of 15 age cohorts between studies SBG and KG 2 the respective increments in mean were found to be statistically significant (Table 5).

Biacromial diameter

The maximum increment of mean value of biacromial diameter in boys occurred between studies SBG and KG 1 was 2.9 cm (13.0 years). However, between studies KG 1 and KG 2 it was observed to be in the order of 0.7 cm (14.0 years). Between studies SBG and KG 2, the mean value increased by 3.4 cm (14.0 years). In all 10 age cohorts between studies SBG and KG 1 and in 4 of 10 age cohorts between studies KG 1 and KG 2 and in 14 of 15 age cohorts between studies SBG and KG 2 the increments were found to be statistically significant. As exception between studies KG 1 and KG 2, there was a decline of mean value (-0.2 cm) at 7.0 years (Table 6).

Bi-iliocristal diameter

In case of bi-iliocristal diameter, the maximum increment in mean values among boys between studies SBG and KG 1 was 1.3 cm (14.0 years) while the corresponding highest increment between studies KG 1 and KG 2 was observed to be 0.9 cm (16.0 years). However, between studies SBG and KG 2 the highest increase of mean value was observed to be 2.1 cm (14.0 years). In 9 of 10 age cohorts between studies SBG and KG 1, in 9 of 10 age cohorts between studies KG 1 and KG 2 and in 12 of the 15 age cohorts between studies SBG and KG 2 the increments in mean were found to be statistically significant. As exception, between study KG 1 and study KG 2 there was a decline of mean (-0.2 cm.) at 7.0 years and again between studies SBG and KG 2 there was another decline of mean (-0.1cm) at 21.0 years (Table 7).

TABLE 5. Changes in mean values of subischial leg length (cm) by age in boys over three study periods.

Age (years)	SBG# (1952-1966)				KG 1# (1982-1983)				KG 2# (1999-2011)				Difference of mean values (cm) between study periods		
	n	Mean	sd	se	n	Mean	sd	se	n	Mean	sd	se	SBG vs KG 1	KG 1 vs KG 2	SBG vs KG 2
7.0	105	50.5	3.3	0.33	58	54.7	4.1	0.53	122	55.6	2.7	0.25	4.2**	0.9	5.1**
8.0	129	53.9	3.1	0.28	83	57.7	3.3	0.37	119	59.1	3.3	0.30	3.8**	1.4*	5.2**
9.0	139	56.8	3.3	0.28	93	60.3	3.4	0.35	126	62.6	3.8	0.34	3.5**	2.3**	5.8**
10.0	134	59.7	3.3	0.28	66	63.1	3.5	0.43	114	65.4	3.8	0.36	3.4**	2.3**	5.7**
11.0	138	62.0	3.5	0.30	93	66.6	4.2	0.44	123	68.7	4.4	0.40	4.6**	2.1**	6.7**
12.0	140	64.9	3.9	0.33	94	69.5	5.3	0.54	146	71.9	5.0	0.41	4.6**	**2.4****	7.0**
13.0	138	67.8	4.2	0.35	93	73.6	4.3	0.45	159	75.5	4.5	0.36	**5.8****	1.9*	**7.7****
14.0	118	71.8	5.0	0.47	87	76.6	5.0	0.54	135	78.9	4.1	0.35	4.8**	2.3*	7.1**
15.0	123	75.4	4.6	0.41	69	78.9	3.5	0.42	122	79.7	4.5	0.41	3.5**	0.8	4.3**
16.0	106	77.6	4.1	0.40	32	79.6	3.3	0.58	131	81.6	3.9	0.34	2.0*	2.0*	4.0**
17.0	103	78.5	3.7	0.37	NA	NA	NA	NA	123	80.8	4.2	0.38	NA	NA	2.3**
18.0	91	79.6	3.8	0.4	NA	NA	NA	NA	109	81.1	4	0.39	NA	NA	1.5*
19.0	81	79.8	3.9	0.43	NA	NA	NA	NA	121	81	4.4	0.4	NA	NA	1.2*
20.0	70	79.2	3.8	0.46	NA	NA	NA	NA	127	81.6	3.7	0.33	NA	NA	2.4**
21.0	23	79.6	4.6	0.96	NA	NA	NA	NA	120	81.2	4.3	0.39	NA	NA	1.6

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 1: Kolkata growth study 1; KG 2: Kolkata growth study 2. NA: Not available. Digits in bold font indicate highest values in the particular columns.

TABLE 6. Changes in mean values of biacromial diameter (cm) by age in boys over three study periods.

Age (years)	SBG# (1952-1966)				KG 1# (1982-1983)				KG 2# (1999-2011)				Difference of mean values (cm) between study periods		
	n	Mean	sd	se	n	Mean	sd	se	n	Mean	sd	se	SBG vs KG 1	KG 1 vs KG 2	SBG vs KG 2
7.0	107	23.8	1.2	0.12	59	25.4	1.6	0.20	123	25.2	1.3	0.12	1.6 **	-0.2	1.4**
8.0	132	24.7	1.1	0.10	82	26.2	1.4	0.15	124	26.3	1.5	0.13	1.5 **	0.1	1.6**
9.0	141	25.6	1.3	0.11	93	27.3	1.6	0.17	130	27.6	1.8	0.16	1.7 **	0.3	2.0**
10.0	138	26.6	1.3	0.11	69	28.0	1.7	0.20	117	28.5	1.6	0.15	1.4 **	0.5*	1.9**
11.0	144	27.3	1.4	0.12	92	29.1	2.0	0.20	123	29.5	1.8	0.16	1.8 **	0.4*	2.2**
12.0	145	28.2	1.5	0.12	92	30.2	2.1	0.22	134	30.6	2.1	0.18	2.0 **	0.4	2.4**
13.0	141	29.1	1.7	0.14	93	32.0	2.2	0.23	149	32.3	2.1	0.18	**2.9** **	0.3	3.2**
14.0	137	30.7	2.0	0.17	90	33.4	2.5	0.27	136	34.1	1.9	0.17	2.7 **	**0.7***	**3.4****
15.0	139	32.1	2.3	0.19	71	34.5	2.0	0.24	126	35.1	1.9	0.17	2.4 **	0.6*	3.0**
16.0	123	33.6	2.0	0.18	33	35.9	2.0	0.35	138	36.4	1.8	0.15	2.3 **	0.5	2.8**
17.0	118	34.7	2	0.19	NA	NA	NA	NA	141	36.3	2.1	0.18	NA	NA	1.6**
18.0	96	35.7	1.8	0.18	NA	NA	NA	NA	128	36.1	2.3	0.2	NA	NA	0.4
19.0	92	36.1	1.6	0.17	NA	NA	NA	NA	131	37.8	1.9	0.17	NA	NA	1.7**
20.0	78	36.3	1.7	0.19	NA	NA	NA	NA	135	38.2	1.8	0.15	NA	NA	1.9**
21.0	29	36.5	1.5	0.29	NA	NA	NA	NA	132	37.5	2.2	0.19	NA	NA	1.0*

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 1: Kolkata growth study 1; KG 2: Kolkata growth study 2. NA: Not available. Digits in bold font indicate highest values in the particular columns.

TABLE 7. Changes in mean values of bi-iliocristal diameter (cm) in boys over three study periods.

Age (years)	SBG# (1952-1966)				KG 1# (1982-1983)				KG 2# (1999-2011)				Difference of mean values (cm) between study periods		
	n	Mean	sd	se	n	Mean	sd	se	n	Mean	sd	se	SBG vs KG 1	KG 1 vs KG 2	SBG vs KG 2
7.0	104	17.2	1.0	0.10	58	17.9	1.1	0.14	123	17.7	1.2	0.11	0.7**	-0.2	0.5**
8.0	128	17.8	0.9	0.08	80	18.3	1.0	0.12	124	18.7	1.2	0.11	0.5**	0.4 *	0.9**
9.0	134	18.3	1.0	0.09	88	18.9	1.0	0.11	129	19.5	1.5	0.13	0.6**	0.6 **	1.2**
10.0	134	18.9	1.0	0.08	64	19.6	1.1	0.14	117	20.0	1.3	0.12	0.7**	0.4 *	1.1**
11.0	142	19.5	1.0	0.08	89	20.2	1.3	0.13	123	20.7	1.5	0.13	0.7**	0.5 *	1.2**
12.0	143	20.1	1.2	0.10	91	20.9	1.6	0.17	134	21.6	1.6	0.14	0.8**	0.7 **	1.5**
13.0	137	20.9	1.3	0.11	91	22.1	1.5	0.16	149	22.5	1.5	0.12	1.2**	0.4 *	1.6**
14.0	135	21.9	1.5	0.13	91	23.2	1.7	0.17	135	24.0	1.5	0.13	**1.3****	0.8 **	**2.1****
15.0	134	22.9	1.5	0.13	71	23.8	1.5	0.18	125	24.4	1.8	0.16	0.9**	0.6 *	1.5**
16.0	120	23.9	1.4	0.12	32	24.1	1.4	0.25	138	25.0	1.6	0.14	0.2	**0.9** *	1.1**
17.0	114	24.5	1.4	0.13	NA	NA	NA	NA	142	25.2	1.9	0.16	NA	NA	0.7*
18.0	90	24.9	1.2	0.12	NA	NA	NA	NA	127	25.1	2	0.18	NA	NA	0.2
19.0	88	25.2	1.4	0.15	NA	NA	NA	NA	129	25.5	1.8	0.16	NA	NA	0.3
20.0	77	25.2	1.4	0.16	NA	NA	NA	NA	134	26	1.7	0.15	NA	NA	0.8**
21.0	29	25.6	1.4	0.25	NA	NA	NA	NA	129	25.5	1.7	0.15	NA	NA	-0.1

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 1: Kolkata growth study 1; KG 2: Kolkata growth study 2. NA: Not available. Digits in bold font indicate highest values in the particular columns.

Girls

Standing height

The magnitude of maximum increment in standing height among girls was observed to be 11.8 cm at 10.0 years and 11.0 years between the two comparing studies (SBG and KG 2). In 14 of 15 age cohorts the increments in mean were found to be statistically significant (Table 8).

Sitting height

Results showed the highest increment in mean value of sitting height among girls in between two studies was 5.8 cm (11.0 years). Moreover, in all 15 age cohorts the increments in mean were found to be statistically significant (Table 9).

Subischial leg length

The highest increment in mean of subischial leg length between the two comparing studies was 6.8 cm (at 10.0 year). In 14 of 15 age cohorts the differences in mean subischial leg length between the comparing studies were statistically significant (Table 10).

Biacromial diameter

Results showed that the highest increment in mean of biacromial diameter in girls between studies SBG and KG 2 was 3.1 cm (13.0 year). In 14 of the 15 age cohorts these increments were found to be statistically significant (Table 11).

Bi-iliocristal diameter

In Table 12, data showed that the highest mean of bi-iliocristal diameter between the two comparing studies was 1.5 cm that was found at three ages, namely 11.0, 12.0, and 13. 0 years. Unusually several declines (-0.3 cm. to -1.1cm) were also recorded between the ages 18.0-21.0 years. In 11 of 15 age cohorts these differences in mean were statistically significant.

TABLE 8. Changes in mean values of standing height (cm) in girls over two study periods.

Age (years)	SBG# (1952-1966)				KG 2 (2005-2011)				Difference of mean values (cm) between study periods
	n	Mean	sd	se	n	Mean	sd	se	
7.0	112	110.1	4.8	0.45	154	118.2	5.1	0.41	8.1 **
8.0	106	115.0	4.7	0.46	155	124.6	5.6	0.45	9.6 **
9.0	119	120.4	5.1	0.47	150	131.3	6.7	0.55	10.9 **
10.0	119	125.3	6.1	0.56	160	137.1	6.1	0.49	**11.8** **
11.0	102	130.4	5.7	0.56	143	142.2	6.8	0.57	**11.8** **
12.0	113	136.6	6.9	0.65	143	147.2	6.9	0.57	10.6 **
13.0	111	141.7	7.0	0.66	140	151.5	5.4	0.45	9.8 **
14.0	105	146.8	6.4	0.63	140	152.6	5.3	0.44	5.8 **
15.0	90	148.9	5.2	0.54	147	154.0	5.6	0.46	5.1 **
16.0	90	149.8	5.2	0.54	135	154.2	5.5	0.47	4.4 **
17.0	88	150.7	4.7	0.50	138	155.5	5.5	0.46	4.8 **
18.0	60	151.7	5.0	0.64	135	155.0	5.5	0.47	3.3 **
19.0	50	151.4	5.1	0.71	146	155.4	6.0	0.50	4.0 **
20.0	41	151.2	5.0	0.79	157	155.3	6.0	0.48	4.1 **
21.0	11	151.3	6.1	1.83	140	154.0	5.3	0.45	2.7

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 2: Kolkata growth study 2. Digits in bold font indicate highest values in the particular columns.

TABLE 9. Changes in mean values of sitting height (cm) in girls over two study periods.

Age (years)	SBG# (1952-1966)				KG 2 (2005-2011)				Difference of mean values (cm) between study periods
	n	Mean	sd	se	n	Mean	sd	se	
7.0	112	60.0	2.3	0.22	151	63.3	2.8	0.23	3.3**
8.0	108	62.0	2.3	0.22	141	65.5	2.9	0.25	3.5**
9.0	121	64.3	2.5	0.22	141	68.2	3.4	0.29	3.9**
10.0	120	66.1	2.8	0.25	149	71.1	3.5	0.29	5.0**
11.0	107	68.3	2.8	0.27	135	74.1	3.6	0.31	**5.8****
12.0	118	71.0	3.4	0.32	134	76.4	3.8	0.33	5.4**
13.0	113	73.6	3.5	0.33	131	78.9	3.0	0.27	5.3**
14.0	108	76.4	3.3	0.31	131	79.3	3.0	0.26	2.9**
15.0	88	77.8	2.5	0.27	134	80.7	2.8	0.25	2.9**
16.0	86	78.4	2.7	0.29	126	80.9	2.8	0.25	2.5**
17.0	84	79.2	2.6	0.28	126	82.2	2.9	0.26	3.0**
18.0	59	79.7	2.5	0.33	127	81.5	2.8	0.25	1.8**
19.0	51	79.7	2.6	0.37	134	81.7	3.4	0.29	2.0**
20.0	40	79.5	2.6	0.40	139	81.7	3.2	0.27	2.2**
21.0	12	79.6	2.8	0.82	126	81.5	2.7	0.24	1.9*

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 2: Kolkata growth study 2. Digits in bold font indicate highest values in the particular columns.

TABLE 10. Changes in mean values of subischial leg length (cm) in girls over two study periods.

Age (years)	SBG# (1952-1966)				KG 2 (2005-2011)				Difference of mean values (cm) between study periods
	n	Mean	sd	se	n	Mean	sd	se	
7.0	112	50.1	3.1	0.29	151	54.8	2.9	0.24	4.7**
8.0	106	53.1	3.1	0.30	141	58.9	3.4	0.28	5.8**
9.0	119	56.1	3.3	0.30	141	62.8	4.0	0.33	6.7**
10.0	119	59.2	3.8	0.35	148	66.0	3.5	0.28	**6.8****
11.0	102	62.1	3.6	0.35	135	68.0	3.8	0.33	5.9**
12.0	113	65.5	4.1	0.39	134	70.8	3.7	0.32	5.3**
13.0	111	68.0	4.2	0.40	131	72.5	3.5	0.30	4.5**
14.0	105	70.4	4.0	0.39	131	73.1	3.3	0.29	2.7**
15.0	86	71.2	3.5	0.38	134	73.1	3.7	0.32	1.9**
16.0	85	71.5	3.4	0.37	126	73.1	3.3	0.29	1.6**
17.0	84	71.5	3.3	0.36	126	73.2	3.6	0.32	1.7**
18.0	59	72.0	3.2	0.42	127	73.3	3.7	0.33	1.3*
19.0	50	71.7	3.1	0.44	134	73.4	3.4	0.29	1.7*
20.0	40	71.6	3.2	0.50	139	73.4	3.9	0.33	1.8*
21.0	11	72.0	4.0	1.20	126	72.6	3.5	0.31	0.6

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 2: Kolkata growth study 2. Digits in bold font indicate highest values in the particular columns.

TABLE 11. Changes in mean values of biacromial diameter (cm) in girls over two study periods.

Age (years)	SBG# (1952-1966)				KG 2 (2005-2011)				Difference of mean values (cm) between study periods
	n	Mean	sd	se	n	Mean	sd	se	
7.0	115	23.5	1.2	0.11	150	25.2	1.6	0.13	1.7**
8.0	107	24.5	1.2	0.12	145	26.8	1.7	0.14	2.3**
9.0	122	25.4	1.3	0.12	145	28.3	1.7	0.14	2.9**
10.0	126	26.4	1.4	0.13	151	29.3	1.8	0.15	2.9**
11.0	110	27.5	1.4	0.14	133	30.5	1.9	0.16	3.0**
12.0	119	28.5	1.8	0.17	137	31.5	1.9	0.16	3.0**
13.0	117	29.8	1.9	0.17	132	32.9	1.9	0.17	**3.1****
14.0	120	30.9	1.8	0.17	136	33.4	1.6	0.14	2.5**
15.0	102	31.7	1.6	0.16	136	33.8	1.6	0.14	2.1**
16.0	97	32.0	1.6	0.16	130	33.9	1.5	0.14	1.9**
17.0	89	32.3	1.7	0.18	129	34.1	1.6	0.14	1.8**
18.0	70	32.8	1.6	0.19	125	34.0	1.6	0.14	1.2**
19.0	53	32.6	1.6	0.22	128	34.1	1.6	0.14	1.5**
20.0	47	32.8	1.7	0.24	135	34.1	1.7	0.14	1.3**
21.0	15	33.5	2.1	0.55	122	34.0	1.5	0.13	0.5

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 2: Kolkata growth study 2. Digits in bold font indicate highest values in the particular columns.

TABLE 12. Changes in mean values of bi-iliocristal diameter (cm) in girls over two study periods.

Age (years)	SBG# (1952-1966)				KG 2 (2005-2011)				Difference of mean values (cm) between study periods
	n	Mean	sd	se	n	Mean	sd	se	
7.0	107	17.0	0.9	0.08	150	17.2	1.3	0.11	0.2
8.0	104	17.6	0.9	0.09	148	18.5	1.5	0.12	0.9 **
9.0	116	18.3	0.9	0.09	146	19.6	1.5	0.13	1.3 **
10.0	121	19.1	1.1	0.10	152	20.5	1.6	0.13	1.4 **
11.0	108	19.9	1.2	0.11	136	21.4	1.7	0.15	**1.5** **
12.0	115	20.9	1.5	0.14	137	22.4	1.7	0.14	1.5 **
13.0	113	22.0	1.5	0.15	132	23.5	1.6	0.14	1.5 **
14.0	118	23.2	1.4	0.13	136	24.2	1.7	0.15	1.0 **
15.0	94	23.9	1.4	0.14	136	24.3	1.6	0.14	0.4 *
16.0	91	24.2	1.3	0.14	130	24.8	1.7	0.15	0.6 *
17.0	88	24.8	1.3	0.14	129	24.9	1.7	0.15	0.1
18.0	63	25.2	1.4	0.18	125	24.9	1.7	0.15	-0.3
19.0	51	25.1	1.6	0.22	129	24.7	1.8	0.16	-0.4
20.0	42	25.4	1.2	0.19	138	24.7	1.8	0.15	-0.7 *
21.0	14	25.9	1.5	0.39	122	24.8	1.8	0.16	-1.1 *

* p value <0.05, ** p value <0.001; n: sample size; sd: Standard deviation; se: Standard error. # SBG: Sarsuna-Barisha growth study; KG 2: Kolkata growth study 2. Digits in bold font indicate highest values in the particular columns.

To summarize, it will be important to mention that for all five body dimensions, the maximum secular gain in both sexes took place during adolescent years. Moreover, greater magnitude of gain was noticed among boys than in girls. These two trends were very consistently observed to reflect sex difference in the onset of adolescent growth spurt. Exceptionally in a very few age cohorts, mean values were also found to have declined which was especially noticed for two width measures. However, among two width measures, greater magnitude of gain was noticed for biacromial diameter than bi-iliocristal diameter in both sexes between studies SBG and KG 2.

2. Secular trends in age specific highest value of standard deviation.

Age specific highest values of standard deviation for standing height in both sexes manifested a consistent pattern of the advancement of adolescent growth spurt over the comparing study periods. For example, in boys of SBG study, the highest standard deviation in standing height was 8.2 cm, noticed at 15.0 years of age while in both studies of KG 1 and KG 2, the highest standard deviation values (8.8 cm and 8.3 cm respectively) were found three years ahead, i.e. at 12.0 years of age (Table 3). Similarly for girls of SBG study, the highest standard deviation (7.0 cm) of standing height was observed at 13.0 years while in KG 2 study it was 6.9 cm observed at 12.0 years of age (Table 8). Two major constituents of standing height, namely, sitting height and subischial leg length also followed this pattern in a very consistent way (Tables 4, 5, 9, and 10). However, for two width dimensions, namely, biacromial and bi-iliocristal diameters, this trend was not observed in both sexes (Tables 6, 7, 11, and 12).

3. Secular trends in biological parameters of adolescent growth spurt.

Boys

Average age at maximum increment

Mean age at maximum increment for standing height has declined between studies SBG and KG 1 by 1.33 years and between studies KG 1 and KG 2 by 0.13 years (Table 13). However, highest decline of 1.46 years was noticed between studies SBG and KG 2. Similarly, for sitting height, the first two declines (SBG to KG 1 and KG 1 to KG 2) were by 1.26 years and 0.26 year respectively while the highest decline by 1.52 years was observed between studies SBG and KG 2. For subischial leg length, the declining values between studies were in the order of 1.39 years, 0.02 year, and 1.41 years respectively. For biacromial diameter, the declining orders of mean ages in three pairs of comparing study periods (SBG-KG 1, KG 1-KG 2, and SBG-KG 2) were by 1.69 years, 0.45 year and 2.14 years respectively. As exception, the decline of mean age at maximum increment for bi-iliocristal diameter in the first pair of studies (SBG-KG 1) was little lower (by 0.50 year) than in the second one (KG 1-KG 2: by 0.99 year) while between studies SBG and KG 2 the decline was observed to be the highest (by 1.49 years).

TABLE 13. Changes in average biological parameters (mean) of adolescent growth spurt in boys, estimated by Preece-Baines growth model 1 (Preece & Baines, 1978) over three study periods

Anthropometric traits	Mean age at maximum increment (year)			Mean peak velocity (cm/year)			Mean final or mature size (cm)		
	SBG* (1952-66)	KG 1* (1982-83)	KG 2* (1999-2011)	SBG* (1952-66)	KG 1* (1982-83)	KG 2* (1999-2011)	SBG* (1952-66)	KG 1* (1982-83)	KG 2* (1999-2011)
	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)	Mean (se)
Standing height	14.37 (0.19)	13.04 (0.58)	**12.91 (0.45)**	7.10 (0.68)	7.23 (1.99)	6.66 (1.45)	166.47 (0.26)	167.63 (1.71)	**169.33 (0.36)**
Sitting height	14.84 (0.21)	13.58 (0.74)	**13.32 (0.70)**	3.53 (0.41)	3.56 (1.54)	3.09 (1.19)	87.13 (0.18)	87.63 (1.63)	**88.35 (0.32)**
Subischial leg length	13.94 (0.20)	12.55 (0.45)	**12.53 (0.37)**	3.83 (0.40)	3.88 (0.77)	3.77 (0.68)	79.44 (0.13)	80.35 (0.50)	**81.23 (0.16)**
Biacromial diameter	14.96 (0.17)	13.27 (0.85)	**12.82 (2.92)**	1.58 (0.14)	1.58 (0.58)	1.41 (2.01)	36.40 (0.07)	36.75 (0.69)	**37.86 (0.45)**
Bi-iliocristal diameter	14.45 (0.13)	13.95 (1.30)	**12.96 (1.30)**	1.06 (0.07)	1.07 (0.64)	0.99 (0.64)	25.27 (0.03)	**26.41 (0.15)**	25.62 (0.15)

* SBG: Sarsuna-Barisha growth study; KG 1: Kolkata growth study 1; KG 2: Kolkata growth study 2; se: Standard error. Digits in bold font indicate highest/lowest values in the particular parameters.

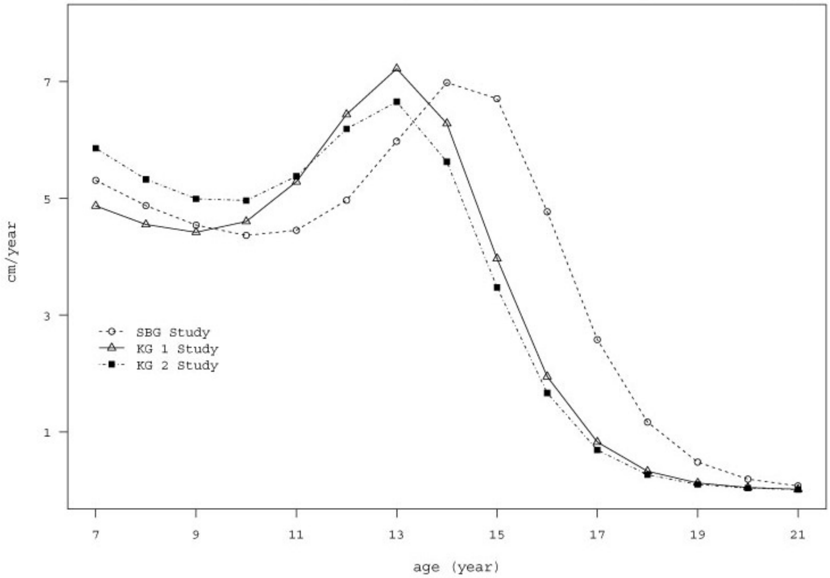

Figure 1. Cross sectional average growth velocity curves – standing height – boys

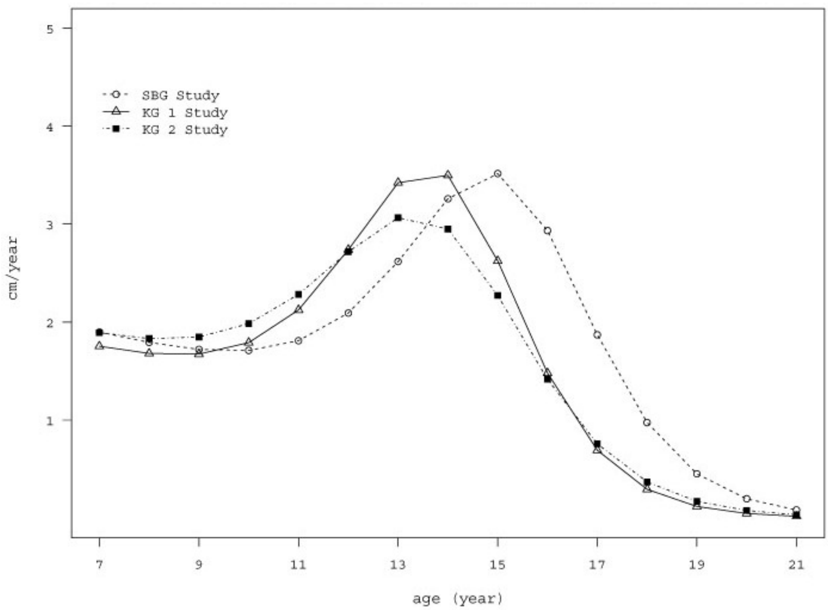

Figure 2. Cross sectional average growth velocity curves – sitting height – boys

Average peak velocity

The second parameter of the adolescent growth spurt, i.e. mean peak velocity has not manifested any consistent trend over the comparing study periods. However, between the time period of studies SBG and KG 1, four of the five investigated traits have manifested increased values of mean peak velocity (standing height by 0.13 cm, sitting height by 0.03 cm, subischial leg length by 0.05 cm, and bi-iliocristal diameter by 0.01 cm). As an exception, for biacromial diameter the value did not change between the first two study periods. On the contrary, between studies KG 1 and KG 2 and again between studies SBG and KG 2, mean peak velocities of all five investigated traits have consistently declined though in varied magnitudes (Table 13).

Average final or mature size

The mean values of final or mature size of five studied anthropometric traits, as expected, have manifested in general, a trend of increase between three pairs of the comparing study periods (SBG-KG 1, KG 1-KG 2, and SBG-KG 2) saving a few exceptions. The magnitude of increase was also depending on the time interval between the comparing study periods. For example, between studies SBG and KG 1 the increase in mean of standing height was 1.16 cm, which was lower than the increase noticed between studies KG 1 and KG 2 (1.70 cm). However, between the study periods of SBG and KG 2, the increase was observed to be the highest (2.86 cm).The same trend was evident for three other body segments, namely, sitting height, subischial leg length, and biacromial diameter. For sitting height, between comparing pairs of study periods, the respective increasing orders of mean values were 0.50 cm, 0.72 cm, and 1.22 cm. For subischial leg length, they were 0.91cm, 0.88 cm, and 1.79 cm while for biacromial diameter the increasing orders were 0.35 cm, 1.11cm, and 1.46 cm respectively. However, the changes of mean values were observed not to be very consistent with respect to bi-iliocristal diameter. Between studies SBG and KG 1, the mean value for final size of bi-iliocristal diameter increased by 1.14 cm while in the second pair of comparison (between studies KG 1 and KG 2) it has unexpectedly declined by 0.79 cm. However, between studies SBG and KG 2 (longer time difference) it has again increased by only 0.35 cm (Table 13).

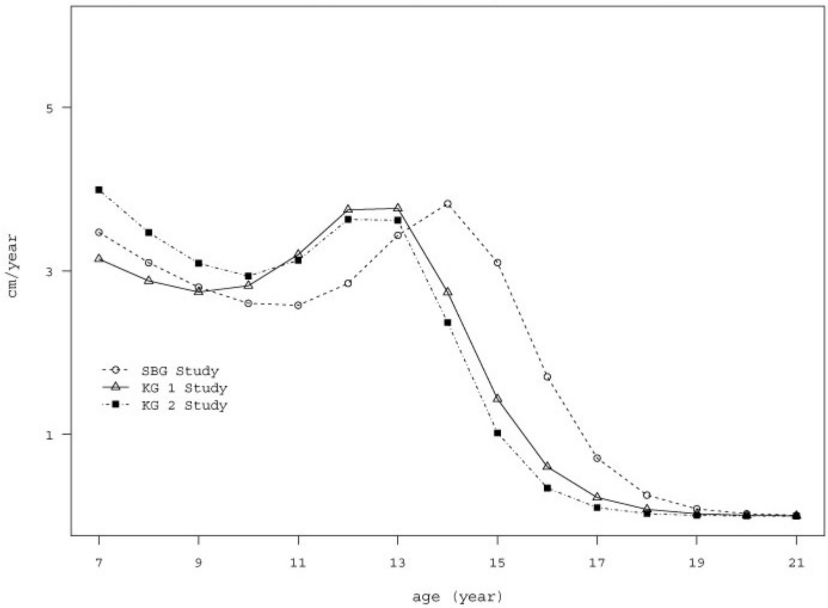

Figure 3. Cross sectional average growth velocity curves – SLL – boys (SLL – subischial leg length)

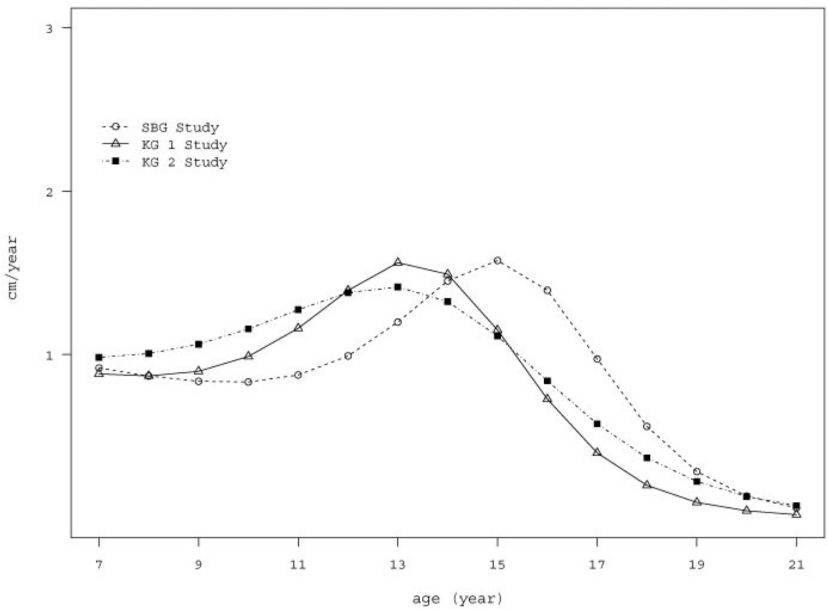

Figure 4. Cross sectional average growth velocity curves – BAD – boys (BAD – biacromial diameter)

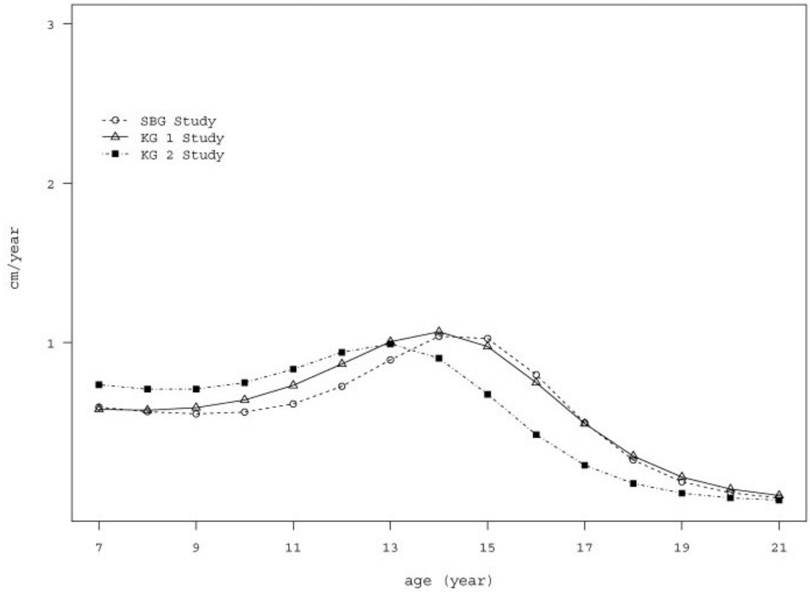

Figure 5. Cross sectional average growth velocity curves – BILCD – boys (BILCD – bi-iliocristal diameter)

Girls

Average age at maximum increment

Secular changes in mean age of maximum increment of standing height could not be evaluated using Preece Baines model 1 due to the unavailability of this parameter in KG 2 study (2005-2011). It is important to note that in girls for two variables, namely, sitting height and bi-iliocristal diameter, the mean age at maximum increment, mean peak velocity and mean final size could not be estimated due to some methodological reasons which might be described as follows: The Preece-Baines growth curve has a convex region in between the age at take-off and peak velocity. For some cross-sectional mean values of girls of KG 2 this feature was missing from the observed plot and thereby in this data set a reasonable Preece-Baines model 1 fitting was not available. The convex region might have been obliterated by the process of averaging of individual growth curves that could not be avoided for cross-sectional means. Therefore, due to this reason, the trend as clearly observed for boys was not observed for girls for some traits. Hence, the mean values of three biological parameters of these two traits were replaced by the median values. It might further be noted that due to the same reason, neither mean nor median age of maximum increment as well as mean or median peak velocity of standing height could be estimated from the girls' data of KG 2 study. Nevertheless for the two major segments of standing height, namely, sitting height and subischial leg length, the median and mean ages respectively were possible to calculate. The trend showed that the median age at maximum increment of sitting height has declined by 2.53 years while mean age for subischial leg length has declined by 0.24 years between SBG and KG 2 studies. Again, both mean and median values of age of maximum increment for biacromial and bi-iliocristal diameters have declined by 0.97 and 0.12 years respectively between two study periods (Table 14).

TABLE 14. Changes in average biological parameters (mean/median) of the adolescent growth spurt in girls estimated by Preece-Baines growth model-1 (Preece & Baines, 1978) over two study periods

Anthropometric traits	Mean/median (se)	Mean/median age at maximum increment (year)		Mean/median peak velocity (cm/year)		Mean/median final or mature size (cm)	
		SBG* (1952-66)	KG 2* (2005-2011)	SBG* (1952-66)	KG 2* (2005-2011)	SBG* (1952-66)	KG 2* (2005-2011)
Standing height	Mean (se)	11.97 (0.42)	NA	5.82 (1.07)	NA	151.08 (0.19)	**154.80 (0.22)**
Sitting height	Median (se)	12.42 (0.60)	**9.89 (1.50)**	2.85 (0.95)	3.38 (4.44)	79.38 (0.19)	**81.72 (0.22)**
Subischial leg length	Mean (se)	11.54 (0.49)	**11.30 (0.80)**	3.19 (0.62)	2.65 (0.60)	71.73 (0.09)	**73.15 (0.11)**
Biacromial diameter	Mean (se)	12.41 (0.79)	**11.44 (5.23)**	1.15 (0.42)	1.15 (0.43)	32.55 (0.08)	**34.04 (0.04)**
Bi-iliocristal diameter	Median (se)	12.51 (1.33)	**12.39 (0.56)**	1.08 (0.91)	1.10 (0.30)	25.23 (0.16)	**24.64 (0.07)**

SBG: Sarsuna-Barisha growth study; KG 2: Kolkata growth study 2; NA: Not available; se: Standard error. Digits in bold font indicate highest/ lowest values in the particular parameters.

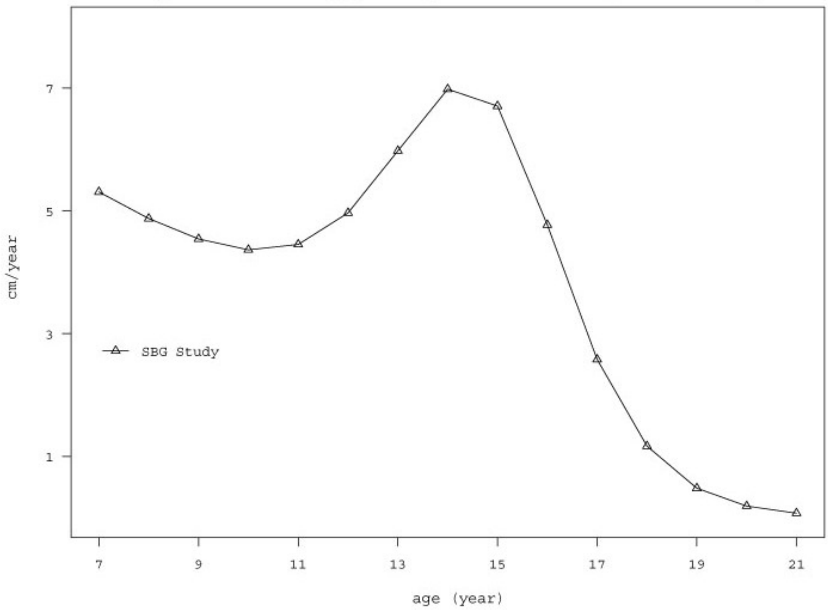

Figure 6. Cross sectional average growth velocity curves – standing height – girls

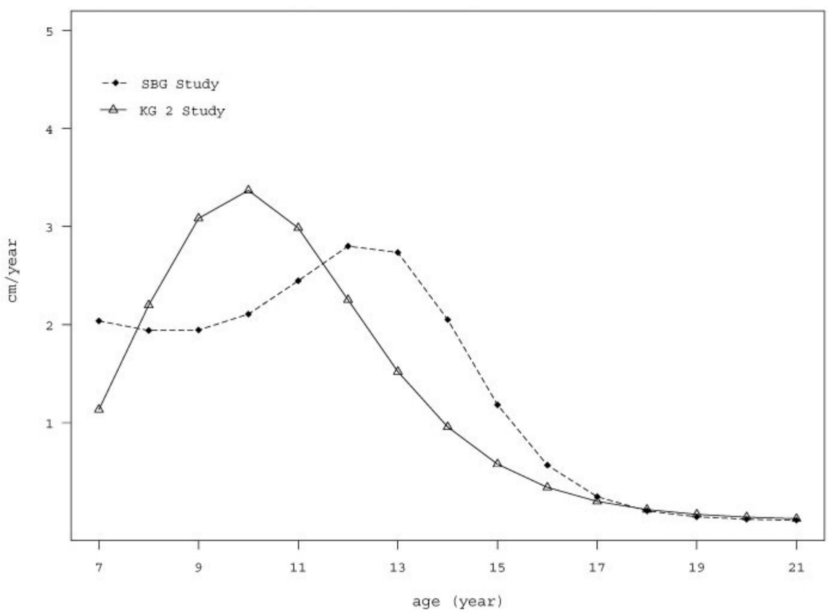

Figure 7. Cross sectional average growth velocity curves – sitting height – girls

Average peak velocity

As stated before, due to methodological reason, among girls mean/median peak velocity for standing height could not be determined from the data of KG 2 study. However, from the remaining four anthropometric traits, in two, namely, sitting height and bi-iliocristal diameter the median peak velocity increased by 0.53 cm and 0.02 cm respectively. On the contrary, for the remaining two traits, while the average peak velocity of subischial leg length decreased by 0.54 cm, the same for biacromial diameter remained unchanged. Therefore, the inconsistent pattern in change of this parameter has been observed in girls (Table 14).

Average mature or final size

Between two comparing study periods (SBG and KG2), mean values of mature size for standing height, subischial leg length, and biacromial diameter have increased by 3.72 cm, 1.42 cm, and 1.49 cm respectively. Moreover, the median mature size of sitting height has increased by 2.34 cm, while unexpectedly the median mature or final size of bi-iliocristal diameter between the two study periods has declined by 0.59 cm (Table 14).

In summary, it can be stated that out of the three investigated biological parameters of adolescent growth spurt, two namely, average age at maximum increment and average final or mature size have presented a firmly consistent pattern of changes over time in both sexes. While the former has declined, the later, on the other hand, has increased over time. Secondly, greater contribution of subischial leg length (1.8 cm) than sitting height (1.2 cm) for secular increase in mean of adult standing height (3.0 cm) has been confirmed by fitting Preece-Baines model 1 to the data of male participants in particular. It has been well illustrated by comparing the respective values obtained from both SBG and KG 2 studies. In addition, the results on secular trend in sex difference of mature size for five body dimensions revealed that in three traits, namely, standing height, sitting height and biacromial diameter, the magnitudes of sex difference have reduced by 0.86 cm, 1.12 cm, and 0.03 cm respectively. On the contrary, for the remaining two traits, namely, subischial leg length and bi-iliocristal diameter, the magnitudes of gender difference have increased by 0.37 cm and 0.94 cm respectively.

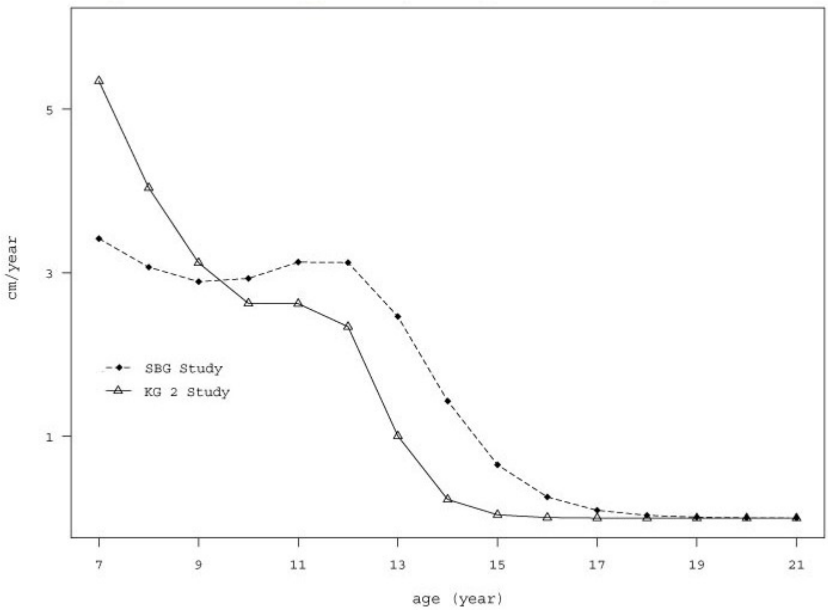

Figure 8. Cross sectional average growth velocity curves – SLL – girls (SLL – subischial leg length)

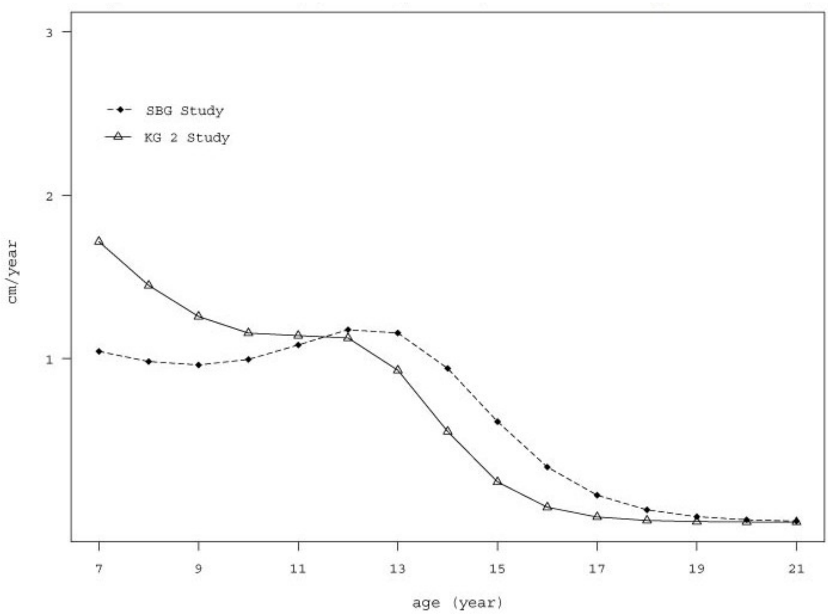

Figure 9. Cross sectional average growth velocity curves – BAD – girls (BAD – biacromial diameter)

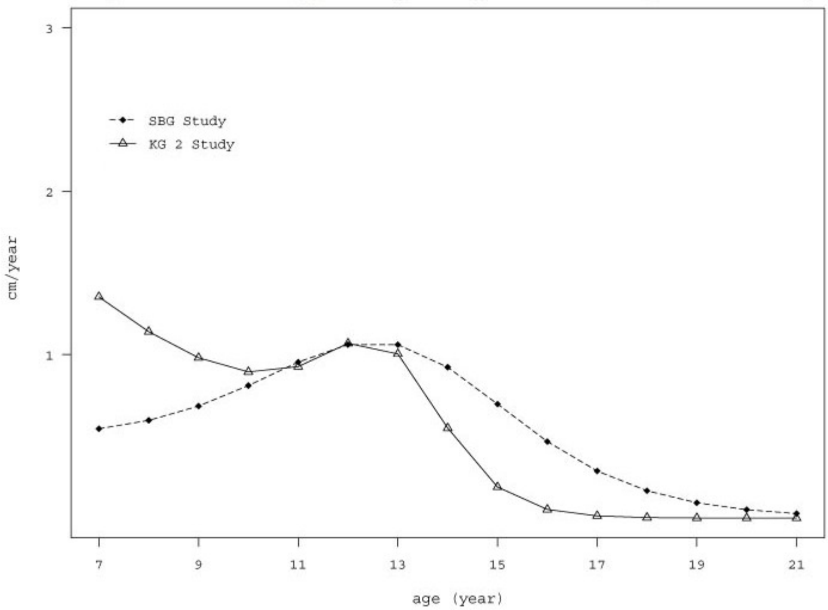

Figure 10. Cross sectional average growth velocity curves – BILCD – girls (BILCD – bi-iliocristal diameter)

Discussion

To the best of our knowledge, the present study has demonstrated for the first time, the occurrence of secular trends phenomena in the measures of physical growth and maturation in an Indian population observed approximately over six decades of time interval. Three linear dimensions (standing height, sitting height and leg length) and two width measures (biacromial diameter and bi-iliocristal diameter) have responded to the phenomena in consistent ways in childhood, during adolescent growth spurt and also in adulthood. In most of the studied age cohorts from 7.0 to 21.0 years, the mean values of the five body dimensions have significantly increased over the time difference of comparing study periods, saving a few exceptions. Therefore, the trends indicated in general that a positive secular phenomenon was operating for these traits in Bengali population. In girls, the highest secular gain has been noticed for mean standing height, sitting height and subischial leg length and also the highest change between age cohorts was about at least two years before than boys that was due to sex differences in the onset of adolescent growth spurt. Among Hong Kong Chinese children, the secular trends in mean standing height with time differences of about 30 years (1963-1993) were reported, where for boys the highest increase of 7.4 cm occurred at 13.0 years of age and for girls such increase in the order of 6.5 cm was noticed at 11.0 years presumably due to sex differences in the onset of the adolescent growth spurt (Leung et al., 1996). However, the magnitude of positive secular trends seems to depend on two criteria. Firstly, on the type of investigated traits (linear or width) and secondly, on the duration of the comparing study periods, i.e. longer the time span, larger will be the amount of secular increase, which in particular, is clearly manifested in the present report, based on three series of growth data available for boys. For example, at 13.0 years of age, secular increase in average standing height between studies SBG-KG 1 and KG 1-KG 2 were 11.6 cm and 2.8 cm respectively while between studies SBG and KG 2 the corresponding increased mean value was the highest, i.e. 14.4 cm.

Two recent studies, one carried out in Hong Kong children (So et al., 2008) and the other among Slovenian children (Kotnik & Golja, 2012) have shown that more secular gain in mean values has resulted due to the increased time difference between comparing studies. Malina and his colleagues (2004) reported that in Oaxaca population from Mexico besides standing height, the average sitting height of boys and girls aged 10 to 13 years increased by 2.6 cm and 2.3 cm respectively in an interval of two decades and the values were less than the increments found for leg length (3.1 cm and 3.2 cm for two sexes). Moreover, body height of the Oaxaca children from Mexico has been studied from 1970 to 1999 in relation to different transitional processes (Malina et al., 2008). It has been found that 30 years of epidemiological transition from stage 1 to stage 2 (changes in age and causes of death) has occurred concurrently with significant secular increase in body height of the children, adolescents and young adults in the population who were in the early stage 2 of demographic transition. The transitional processes have worked synergistically to promote a secular increase in growth and development of children in this community that resulted due to the overall improvements in health, nutrition and living conditions (Malina et al., 2004).

In our study, we found that approximately over six decades of time interval, among the participants of 7.0 to 21.0 years of age, average increase of mean standing height was 8.71 cm for boys and 7.12 cm for girls. The average increments for mean sitting height were 4.16 cm and 3.42 cm and the average increments for mean subischial leg length were 4.51 cm and 3.53 cm in boys and girls respectively. Further, among the width measures, increase in the average biacromial diameter of boys aged 14.0 years was found to be 3.4 cm which was larger than the increase of mean value recorded in German boys (2.2 cm) of same age, studied over two decades from 1975 to 1995 (Kromeyer-Hauschild & Jaeger, 2000), presumably due to the longer time interval of the comparing study period. On the contrary, the increase in average bi-iliocristal diameter of Italian boys aged 7-10 years (Sanna & Soro, 2000) ranged from 1.71 cm to 1.96 cm in two decades (1975-1996) of time span whereas in our study, the corresponding range of increment for this trait was noticeably lower (0.5 cm to 1.2 cm) than these values.

In the present study, with respect to the occurrence of secular trends in the measures of final size, all five dimensions (three linear and two width measures) in both sexes have manifested a significant increase in the contemporary population over decades. A greater contribution of leg length than sitting height for increase in adult height of males was well documented from the results of the study. In Japanese population, an increase in mean adult height of males from 1957 to 1977 was found to be 4.3 cm for which increase of mean values for sitting height and leg length were recorded to be 0.5 cm and 3.8 cm respectively (Tanner et al., 1982). These values have been estimated, like our present study, by fitting Preece Baines model 1 to age specific cross-sectional growth data of different decades. Our results therefore, for the first time have manifested the occurrence of similar phenomenon in an Indian population approximately over six decades of time interval (Table 13). However, for further confirmation of the fact that contemporary Indian males are longer legged than sitting height, future investigations are required. Increased leg length in adults due to the change of time has been stated to be a sensitive indicator of childhood socioeconomic conditions (Gunnell et al., 1998) and it has also been found to be more eco-sensitive in boys than in girls. This was further evident from the studies performed in one transitional country of Eastern Europe, namely, Poland (Grabowska, 2001; Zadzinska et al., 2012). Thus in both sexes, a greater gain during the adolescent years than in adulthood supports the fact that the adolescent period is more sensitive to positive secular trend phenomena than other periods of life (Eveleth & Tanner, 1990; Sousa et al., 2012).

Among the features of adolescent growth spurt, the trend of its early onset in the contemporary Bengali population was also reflected from the analysis of data for standing height, sitting height and subischial leg length. This has been well documented from the pattern of advancement in age specific highest standard deviation values of these three dimensions over the comparing study periods. From the observed trend, it became quite apparent that the adolescent growth spurt has been initiated in the contemporary Bengali population about two years before than the Bengali population examined about six decades ago from the same region (SBG study of 1952-1966).

The second important feature of the secular trends phenomena in adolescent growth spurt has been manifested in this population through lowering of average age of maximum increment of the five studied traits. In boys, it was clear that longer was the time interval, greater was the declining value of age at maximum increment of the five traits. This was possible to see due to the availability of three data sets collected over three different time periods. However, among girls, declining trend of this parameter continued for four traits (except standing height) between a time interval of SBG and KG 2. Therefore, the overall trend of decline of average ages in both sexes, signify that the contemporary Bengali children, on average, are maturing physically at a faster rate by reaching peak of the adolescent growth spurt early. In Japan, between the periods of 1950 and 2000, mean values of age at peak velocity of standing height, sitting height and subischial leg length of boys also declined by 2.1 years, 2.0 years and 2.0 years, respectively. The corresponding declining values in girls for these traits were 2.1 years, 2.4 years, and 1.7 years respectively (Kagawa & Hills, 2011). In our present study, due to methodological reason we could not estimate the average age at maximum increment for standing height in girls yet the average ages estimated for two other linear traits, namely, sitting height and subischial leg length confirmed the declining trend. A decline in mean age at peak height velocity of

Chinese boys and girls from Taiwan was reported to be 0.044 year/year and 0.050 year/year respectively over twenty five years of time interval (1964-1988) (Huang & Malina, 1995). Again, over two decades of time interval, between 1964-66 and 1983-84, mean age at peak height and weight velocities of Nunoa children from Peru declined by one year on average (Leatherman et al., 1995). All evidences therefore, strongly support and suggest that the contemporary Bengali children are maturing physically at a faster rate than the Bengali children from Kolkata studied about six decades ago. Further, average values of age of maximum increments of two width measures, namely biacromial and bi-iliocristal diameter have also declined in both sexes. According to an earlier report (Malina et al., 2004), the lowering of mean age at peak velocity as an indicator of faster rate of physical maturation could be associated with overall economic progress of the respective countries, observed during transition.

The single measure of sexual maturation examined from the data of Kolkata growth study 2 was mean age at menarche, which has been estimated to be 11.80 year (based on recall data) for urban Bengali Hindu girls of Kolkata city (Dasgupta, 2015) and was found to be lower than the mean age at menarche (12.90 years) reported for Bengali girls from the same place studied about four decades ago (Sarkar & Roy, 1968). The trend therefore, suggested that the contemporary Bengali urban girls were progressing with faster rate of sexual maturation.

The third measure of adolescent growth spurt dealt in the present study was mean peak velocity which has produced an inconsistent trend of change in five anthropometric traits over the study periods. Such an inconsistent trend of change has also resulted earlier in a study among Japanese children (Kagawa & Hills, 2011) where the cross-sectional data of four bodily traits between the periods of 1950 to 2000 have been analysed by fitting the Preece-Baines model 1 to observe the secular phenomena. According to Tanner (Tanner, 1990, personal communication), fitting of Preece-Baines model 1 to cross-sectional averages provided an efficient estimate of two important parameters, namely, mean age at maximum increment and final size and thereby, these two biological parameters were found to have been estimated from the data of Japanese children to evaluate the secular trends phenomena between the period of 1957 and 1977 (Tanner et al., 1982). Another recent study (Mao et al., 2011) have estimated more number of biological parameters of adolescent growth spurt for Chinese children (by fitting Preece-Baines model 1) from a very large cross-sectional data. However, as reported their importance for evaluating the secular trends phenomena needs confirmation from other studies.

In conclusion therefore, it can be stated with sufficient evidences that the contemporary urban Bengali children are having significantly larger body size during most of the growing years and also in adulthood; they have entered adolescent growth spurt about two years before, reached the peak of the adolescent growth spurt about two years earlier than the Bengali children studied about six decades ago from the same region. The contemporary Bengali girls have also matured sexually at a faster rate than the girls investigated about four decades ago. All of these features clearly demonstrated that a positive secular phenomenon on anthropometric characteristics was operating in this population.

Factors responsible for observed trends

An aggregation of multiple factors related to the changes noticed in overall socio-economic, household demographic and public health situation of the Kolkata City people might be attributed as the responsible factors for the observed positive secular trends in anthropometric characteristics of the boys and girls. Although archival data related to six decadal changes in these parameters were not readily available, yet relatively recent short term changes as found in these parameters have convincingly generated useful information for better interpretation of the results.

The first and foremost factor was related to the changes noticed in the level of parental education (mothers in particular). In KG 1 study, among mothers of the participated boys, frequency of education level below secondary (Class 10) was about 36%, which, in KG 2 study (1999-2011) has reduced to 18.6%. On the other hand, between these two study periods, the frequency of mothers with education above Bachelor's Degree has noticeably increased from 19% to 32.47%. These two-way changes clearly suggested that an improvement has taken place in the level of maternal education. In addition, analysis of growth data of two earlier study periods (i.e., 1982-83 and 1999-2001) has also demonstrated the role of maternal education for manifesting a positive trends in several primary growth characteristics (Dasgupta et al., 2008). In the national level, it has been found that overall literacy rate of the Kolkata population has increased from 77.6% in 1991 to 81.3% in 2001 whereas the adult literacy rate has also changed in an increasing order from the year 2001 to 2011. For males, it has increased from 83.79% to 89.08% while for females the respective order of increase was from 77.30% to 84.98% (Census of India, 2011). Other reports also provided enough evidences to conclude that improved parental education to be one of the responsible factors for manifesting positive secular trends in growth of height, body weight and body mass index: a trend was observed from the studies carried out in several transitional countries like Brazil (Monteiro et al., 1994), Taiwan (Huang & Malina, 1995) and Portugal (Padez & Johnston, 1999). Improved growth and nutritional status of children was found to be related with improved maternal education in the families with average socio-economic status (middle-class) (Reed et al., 1996) that was also confirmed from the results of both KG 1 and KG 2 studies (Dasgupta et al., 2008; Dasgupta, 2015).

The second probable factor responsible for the manifestation of positive secular trends might be related to the changes in income and expenditure levels over the comparing study periods. In KG 1 study (1982-83), the distribution of per capita monthly expenditure of the surveyed families was bimodal and accordingly two cut-off values, namely upto INR 250 (<USD 4.2) and greater than INR 250 (≥ USD 4.2) were adopted. It was found that above 58.23% of families were belonging to first category and 41.77% were belonging to the second category. The equivalent value of INR 250 was found to be INR 408 in 2008-2009 (Indian Banks' Association, 2009). Based on this transformed value, it was found that in KG 2 study, per capita monthly family expenditure was more than INR 408, ranging from INR 414.37 to INR 11,031.49 for both sexes, which indicated an esca-

lation in the per capita monthly family expenditure level. Moreover, in the Indian context, the average per capita income per year has increased from INR 1219,155 (1991-92) to INR 4794,227 (2012-13) calculated according to the price index of 2004-2005 (Ministry of Statistics and Programme Implementation, 2014). This increasing trend might be held as one of the responsible factors for improvement in the standard of living of Kolkata population and thereby was more likely to result better growth and nutritional status of the contemporary children. In our previous KG 1 study, we have shown that elevated per capita monthly expenditure of the family over about two decades of time interval was one of the factors responsible for the manifestation of positive secular trends in average height, weight and body mass index of Bengali boys aged 7-16 years (Dasgupta et al., 2008). Improved growth status of contemporary children due to increased income level of the country was also reported from Papua New Guinea (Norgan, 1995) and Brazil (Castilho & Larr, 2001). Such evidences were also available from several countries in economic transition like China (Shen et al., 1996), Ghana (Nube′ et al., 1998), Seychelles (Marques-Vidal et al., 2008), Brazil (Welch et al., 2009), and North East India (Mungrephy & Kapoor, 2010), where changes in economic policies, rapid epidemiological transition and greater economic development, and higher involvement in market economy altogether improved standard of living etc. that were attributed as the contributory factors for obtaining positive secular trends in physical growth of children and body composition in adults. It was also important to note that in KG 2 study, the effect of per capita monthly expenditure level was found to be significant for increased mean values of standing height, subischial leg length, and sitting height. Thus it was apparent that increased level of per capita monthly family expenditure/income of the contemporary families might have acted as one of the contributory factors for observing positive secular trends.

The third probable factor was related to one variable of the household demography, namely size of sibship. A comparison showed that between the time span of growth studies KG 1 and KG 2, the percentage of families with more than one sib has noticeably declined from 29.89% to 4.42% and at the same time the percentage with no sibs has increased from 23.29% to 48.76% (among boys). These two changes clearly demonstrated that the sibship size in the contemporary urban Bengali families has dramatically reduced and this might be held as one of the responsible factors for manifesting positive secular trends in anthropometric parameters. We have also found the growth enhancing effects of smaller sibship size to be significant in most of the body composition related traits (e.g. body weight, skinfolds etc.) investigated in KG 2 study. Studies carried out in several European countries like Scotland, England and the Netherlands have demonstrated that smaller sibship size was one of the determining factors for the observed positive secular trends in standing height and body mass index of children (Chinn et al., 1989; Fredriks et al., 2000). Moreover, in a recent study carried out among 7 to 16 year-old Polish boys, it has been demonstrated that height and body mass index of children with sibship size 1 to 2 were greater than sibship size of 3 or more (Suliga, 2009). Further, in Poland, where the socioeconomic transition has been initiated in 1980, sibship size has been found to have played a more important role than socioeconomic status in explaining the variability in body mass index of children after 1990 (Koziel et al., 2004).

The fourth probable factor may be related with the changes in several basic parameters of public health. Infant mortality rate in Kolkata city has manifested a declining trend from 44% to 25% per thousand individuals between 1988 to 1991 (Dutta Ray, 2002) while for the entire state of West Bengal, the declining trend was from 38% to 35% between the year 2005 and 2011 (Source: State Bureau of Health Intelligence, Directorate of Health Services, Govt of West Bengal, 2011). Another measure, namely, life expectancy at birth in West Bengal has escalated from 57 years to 64 years between 1970-75 and 2001-05 (Government of West Bengal, 2016. www.wbhealth.gov.in, last accessed 18.6.2016) while the child immunization rate has noticeably increased from 52.3% to 70.8% between 1993 and 1996 (Chatterjee & Ghose, 2001). Global literature provides strong support to conclude that few indicators of child health, namely, infant mortality and morbidity rates were also associated with the manifestation of positive secular trends in physical growth and maturation of children (Malina, 1979; Danker-Hopfe, 1986; Sobral, 1990; Blanksby, 1995). Decline of infant and childhood mortality and morbidity rates reflect improved living conditions, sanitation and overall upliftment of public health nutrition (Beunen et al., 2006). Studies carried out in Italy, Austria and Portugal have also shown that the decrease in post neonatal mortality rate with increased level of survival in adulthood were related to the increased mean values of height of population (Ulizzi & Terrenato, 1982; Schmidt et al., 1995; Padez & Johnston, 1999).

Finally, among the three components of Human Development Index, namely, health index, education index and per capita income index estimated for the city of Kolkata, it was seen that the first two indices have increased from 0.73 (in 1981) to 0.82 (in 2004) and from 0.71 (in 1981) to 0.80 (in 2004) while the per capita income index has remained unchanged (0.73) over time. However, the overall value of the Human Development Index for the same time span has increased from 0.74 to 0.78 (Anand & Sen, 1999; West Bengal Human Development Report, 2004). Therefore, the increased value of this index should also be considered as one of the contributory factors for the improvement in socioeconomic conditions of Kolkata people and thereby might be responsible for manifesting positive secular trends in growth and maturation of the contemporary Bengali children of the city. Several researchers (Rousham, 1996; Floyd, 2000) have suggested that there was a continuous need to analyze the relationship between growth and different indicators of socioeconomic and demographic origin in different populations as these factors determined the level of a population's well-being as a part of a transitional process and thereby played significant roles in influencing the pattern of child growth and development (Dasgupta & Weale, 1992).

Limitations of the study

This study has several important limitations for interpreting the results. Firstly, while around the world, the secular growth data are mostly presented by decade/year or even month wise, in the present study it has not been possible to present data according to that fashion. This happened because three growth studies differed in nature with respect to the time span (Table 2). Therefore, in the present communication, the results were compared and interpreted in relation to the time intervals between the performed surveys instead of specifying any decade. Secondly, the sample sizes used in three comparing studies were not representative of the entire middle-class Bengali population from Kolkata City. Therefore, an unequal age distribution of samples in both sexes between three comparing growth surveys might be considered as one of the probable reasons for obtaining few unexpected results (for e.g. negative secular trends). The third limitation pertained to socioeconomic and demographic data. The items of such data collected in KG 1 study and KG 2 studies, have not been collected in SBG study. As a result, time trends in growth variables in relation to the socioeconomic factors were possible to know only for boys by comparing the socio-demographic data from studies KG 1 and KG 2. For girls, such kind of association could not be observed. Therefore, in quantification of the amount of secular changes, all of these limitations should be taken into consideration. Notwithstanding of all these limitations, this study for the first time has demonstrated that a battery of basic parameters of growth and maturation have undergone positive secular trends phenomena in an Indian Bengali young urban population. However, for monitoring its continuity in the population, repetitive studies should be initiated on a large scale.

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Contributions of the authors: Dr. Parasmani Dasgupta developed the research project as principal investigator. Authors have equal contributions towards the preparation of the manuscript.

Conflict of interest: None.

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