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AUXOLOGY OF SRI LANKAN CHILDREN AGE 5 TO 18 YEARS: 3. SITTING HEIGHT AND SUB-ISCHIAL LEG LENGTH

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Summary. Sitting height (SH), leg length (LL) and the ratio, SH/TH have been studied in 9070 school children between 5 and 18 years. SH and LL are not influenced by ethnicity. SH, LL and the overall increment in LL are socio-economic dependent during pre-adolescence. LL velocity is greater than SH velocity during pre-adolescence, so that LL catches up with SH before puberty, which occurs earlier in children of a higher socio-economic status. Children who become tall are those with a high LL velocity during pre-adolescence and a high SH velocity after puberty. Neither poverty nor ethnicity have any influence on the relative proportion of SH to stature.

Key words : Sitting height, leg length, sitting height index, ethnicity, socio-economic status

INTRODUCTION

Data on sitting heights of Sri Lankan adults have been reported by Stoudt (1), who published the results of a study on Ceylonese males carried out by Marett in 1937 / 39, and by Cullumbine and his associates (2, 3) and Chanmugam (4). In Marett's and Cullumbine's studies the mean heights and sitting heights of Tamil males were significantly greater than those of Sinhalese males. The mean of the ratio, sitting height to total height, did not show a constant pattern when the ethnic groups were compared (1, 4).

In a study of medical students in 1979 Balasuriya (5) reported that in Sri Lanka there were no significant differences in the ratio, sitting height to total height, between ethnic groups or between the genders. A comparison of results of this latter study with those of Marett, Cullumbine and Chanmugam showed that all measurements (stature, sitting height, biacromial diameter and the sitting height and biacromial indices) had increased during the past 30-40 years (5).

The sitting heights of school children of Sri Lanka have not been studied. This is a report of a study on 9070 boys and girls between 5 and 18 years of age, attending schools in and around Colombo, catering to three

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different socio - economic-educational status households. The difference between the total standing height or stature (TH) and the sitting height (SH) has been taken to indicate the sub-ischial length (LL). The variations in SH, LL, and the ratio SH/TH with age, gender and ethnic group have been studied.

STUDY POPULATION AND METHODS

The schools selected for the study and the precautions taken when measuring stature have been detailed earlier (6).

Affluent children are represented by boys attending St. Thomas' College Mt. Lavinia and Colombo (STC) and girls attending two convents, St. Bridget's and Holy Family (SBC + HFC) in Colombo. Children attending three schools at Kadawatha come from households of a lower socio - economic - educational status (SEES), living in a semi-urban habitat. Wesley College (WC) in the city draws its boys from househods of SEES in between STC and the Kadawatha schools. Assessment of nutritional status by the Waterlow classification, and by clinical examination of a random sample at STC and all Kadawatha children, showed that STC, SBC and HFC had the lowest number of undernourished children and the Kadawatha schools the highest, WC being in between (6). The mean age at menarche at SBC and HFC was 11.8 years and that at Kadawatha 13.0 years (7).

Sitting height was measured with the child sitting on a stool of known height, specially constructed to fit the base of the Holtain stadiometer used in measuring stature. The child's sacral region and back of head were in contact with the upright of the stadiometer and the legs hung over the edge of the stool. The feet were supported on rungs in the front of the stool (or on the floor, in the case of older children) so that the thighs were parallel to the base of the stadiometer. The head and neck were held upright as in measuring stature. The reading on the digital counter was taken to the last completed 0.1 cm.

All measurements were taken by a team of trained persons (post-graduate students) under the supervision of one of us (TWW).

RESULTS

Tables 1 and 2 and Figs. 1 and 2 show the change of SH and LL with age. Among girls (Fig. 1) LL increases more rapidly with age than does SH and the curves meet between 13 and 13½ years in the case of Kadawatha girls and about 6 months earlier among the more affluent SBC & HFC girls. Thereafter. SH remains higher than LL until adult stature is attained. The situation is similar among boys (Fig. 2). LL catches up with SH at an earlier age at STC (about 10 years) than at WC (13½ years) and

Table 1. Sitting height and leg length (in cm) and sitting height indices (SH/TH X 100) of girls

Age Yrs	SBC & HFC N	SBC & HFC Sitting height Mean	SBC & HFC Sitting height S.D	SBC & HFC Leg length Mean	SBC & HFC Leg length S.D	SBC & HFC SH/TH x 100	Kadawatha N	Kadawatha Sitting height Mean	Kadawatha Sitting height S.D	Kadawatha Leg length Mean	Kadawatha Leg length S.D	Kadawatha SH/TH x 100
5—	174	59.9	2.98	51.6	3.14	53 70	29	55.3	1.96	50.1	3.49	52.50
6—	245	61.6	2.82	55.4	3.74	52.60	29	59.3	2.82	53.1	2.37	52.80
7—	333	64.0	4.08	58.0	4.31	52.50	47	61.0	2.13	54.7	2.77	52.70
8—	285	65.8	2.71	61.2	3.82	51.80	44	62.3	2.27	57.8	2.87	51.90
9—	306	68.2	3.34	64.7	3.91	51.20	30	65.2	2.39	61.7	3.76	51.40
10—	303	70.4	3.58	67.8	4.08	51.00	49	66.7	3.22	64.5	4.10	50.90
11—	338	73.3	4.05	71.4	5.05	50.70	51	70.2	3.19	67.6	4.02	51.00
12—	318	76.1	3.83	74.0	3.84	50.70	29	71.4	3.95	68.7	4.57	51.00
13—	305	77.1	5.13	76.6	4.35	50.10	22	72.8	3.48	72.8	5.91	50.00
14—	286	77.9	4.82	76.8	7.36	50.60	39	75.2	3.19	74.5	4.34	50.20
15—	208	78.9	4.30	76.4	4.77	50.80	69	86.6	10.80	75.3	4.37	53.30
16—	284	79.8	5.03	76.9	5.22	50.90	9	79.8	8.36	75.5	3.87	51.30
17—	243	80.0	3.10	76.7	4.52	51.10	17	79.3	3.80	76.4	4.14	50,90
18—	144	80.8	3.33	76.2	4.61	51.50	17	78.5	5.00	77.5	3.40	50.30

Table 2. Sitting height and leg length (in cm) and sitting height indices (SH/TH x 100) of boys

Age Yrs	STC N	STC Sitting height Mean	STC Sitting height S.D	STC Leg length Mean	STC Leg length S.D	STC SH/TH x 100	Wesley N	Wesley Sitting height Mean	Wesley Sitting height S.D	Wesley Leg length Mean	Wesley Leg length S.D	Wesley SH/TH x 100	Kadawatha- N	Kadawatha- Sitting height Mean	Kadawatha- Sitting height S.D	Kadawatha- Leg length Mean	Kadawatha- Leg length S D	Kadawatha- SH/TH x 100
5 -	108	59.0	2.90	52.6	3.15	52.84	96	58.9	3.07	52.6	5.68	52.81	33	56.2	3.23	50.6	3.0	52.65
6 -	215	61.8	4.31	56.7	4.29	52.08	117	61.2	3.40	54.9	6.24	52.56	31	59.3	2.38	53.8	6.3	52:39
7 -	255	64.1	3.11	59.3	4.52	51.93	130	63.5	3.20	57.7	5.44	51.95	42	61.4	2.88	59.9	4.7	51.89
8 -	176	6.53	3.30	61.8	3.98	51.38	165	65.6	2.76	60.2	5.85	51.93	39	62.9	3.24	60.4	10.0	51 01
9 -	170	67.8	3.06	64.8	3.79	51 13	146	67.5	2.95	63.8	6.66	51.18	36	65.3	2.38	61.1	3.9	51.64
10 -	228	67.6	4.36	67.5	3.71	50.02	180	69.5	3.27	65.9	6.68	50.38	49	67.1	2.60	63.8	4.2	51.29
11 -	176	71.3	4.85	70.6	4.50	50.23	150	70.9	3.34	68.7	7.53	50,25	60	68.1	3.00	66.0	5.0	50.79
12 -	245	74.6	4.41	74.5	5.21	50.03	113	73.8	5.28	72.5	8.34	49.86	24	70.2	3.53	69·9	4.0	50.30
13 -	175	77.0	4.26	77.7	5.54	49.76	134	75.9	4.09	75.2	4.75	49.86	21	71.8	6.47	68.9	6.5	51.04
14 -	221	79.9	5.36	80.1	5.44	49.93	151	78.2	4.15	78.7	8.61	49.32	47	75.1	5.04	75.0	4.7	50.05
15 -	146	83.0	5.87	82.2	4.69	50.25	127	81.6	4.01	81.4	6.87	49.93	62	85.9	12.28	77.5	4.9	52.57
16 -	107	85.3	4.13	83.9	4.37	50.43	52	81.6	5.04	82.1	6.92	49 82	16	90.3	14.58	79.8	4.0	53.08
17 -	87	85.9	3.62	84.7	4.94	50.34	25	8.29	5.13	84.6	7.37	50.21						
18 -	73	86.3	3.10	84.4	4 08	50.55	24	81.4	6.73	84.1	9.19	49.34						

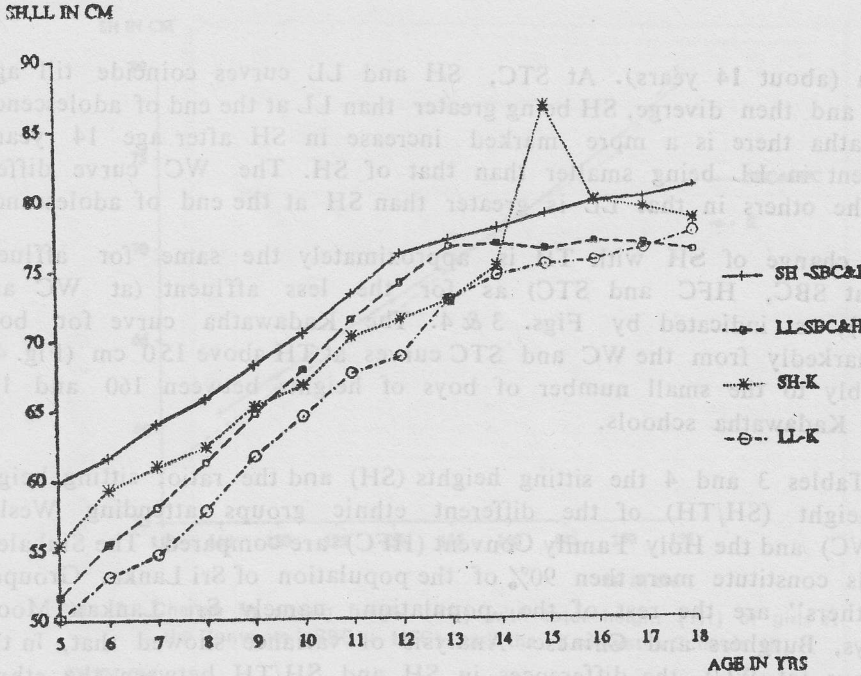

Fig. 1. Distance curves for sitting height (SH) and leg length (LL) for girls at St. Bridget's and Holy Family Convents (SBC + HFC) and in the Kadawatha Schools (K).

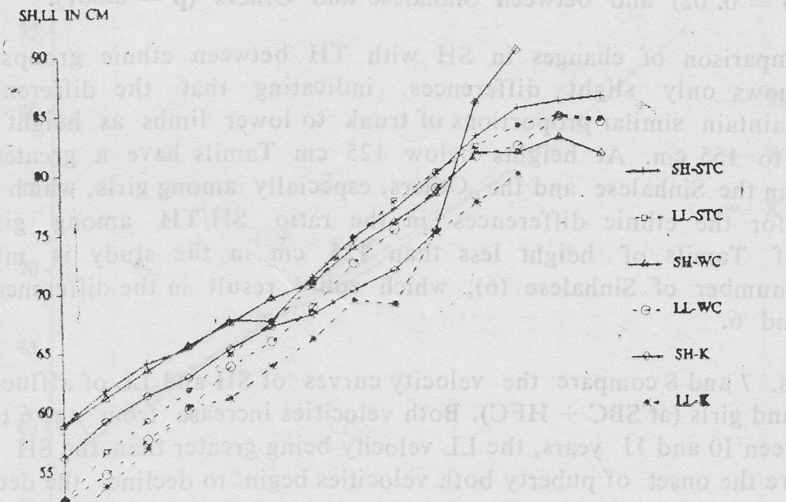

Fig. 2. Distance curves for sitting for height (SH) and leg length (LL) for boys at St. Thomas' College (STC), Wesley College (WC) and the Kadawatha Schools (K).

Kadawatha (about 14 years). At STC, SH and LL curves coincide till age, 14½ years and then diverge, SH being greater than LL at the end of adolescence. At Kadawatha there is a more marked increase in SH after age 14 years, the increment in LL being smaller than that of SH. The WC curve differs from all the others in that LL is greater than SH at the end of adolescence.

The change of SH with TH is approximately the same for affluent children (at SBC, HFC and STC) as for the less affluent (at WC and Kadawatha), as indicated by Figs. 3 & 4. The Kadawatha curve for boys deviates markedly from the WC and STC curves at TH above 150 cm (Fig. 4), due probably to the small number of boys of heights between 160 and 170 cm in the Kadawatha schools.

In Tables 3 and 4 the sitting heights (SH) and the ratio, sitting height to total height (SH/TH) of the different ethnic groups attending Wesley College (WC) and the Holy Family Convent (HFC) are compared. The Sinhalese and Tamils constitute more then 90% of the population of Sri Lanka. Grouped under "Others" are the rest of the population, namely Sri Lankan Moors and Malays, Burghers and Chinese. Analysis of variance showed that, in the case af boys (at WC), the differences in SH and SH/TH between the ethnic groups are not significant. Among girls, too, ethnicity had no influence on SH. However, the ratio SH/TH differed significantly between Sinhalese and Tamils ($p = 0.02$) and between Sinhalese and Others ($p = 0.001$).

Comparison of changes in SH with TH between ethnic groups (Figs. 5 and 6) shows only slight differences, indicating that the different ethnic groups maintain similar proportions of trunk to lower limbs as height increases from 110 to 155 cm. At heights below 125 cm Tamils have a greater sitting height than the Sinhalese and the Others, especially among girls, which probably accounts for the ethnic differences in the ratio SH/TH among girls. The number of Tamils of height less than 125 cm in the study is much less than the number of Sinhalese (6), which could result in the differences seen in Figs. 5 and 6.

Figs. 7 and 8 compare the velocity curves of SH and LL of affluent boys (at STC) and girls (at SBC + HFC). Both velocities increase from age 6 to reach a peak between 10 and 11 years, the LL velocity being greater than the SH velocity. Just before the onset of puberty both velocities begin to decline, the deceleration being greater for LL than for SH. After puberty SH velocity remains slightly higher than the LL velocity, maintaining the ratio SH/TH greater than 0.5 at age 18 years. The velocity curves for Kadawatha boys and girls (not shown) are more erratic, but, as in the case of the more affluent children, the LL velocity is greater than the SH velocity during pre-adolescence. There is

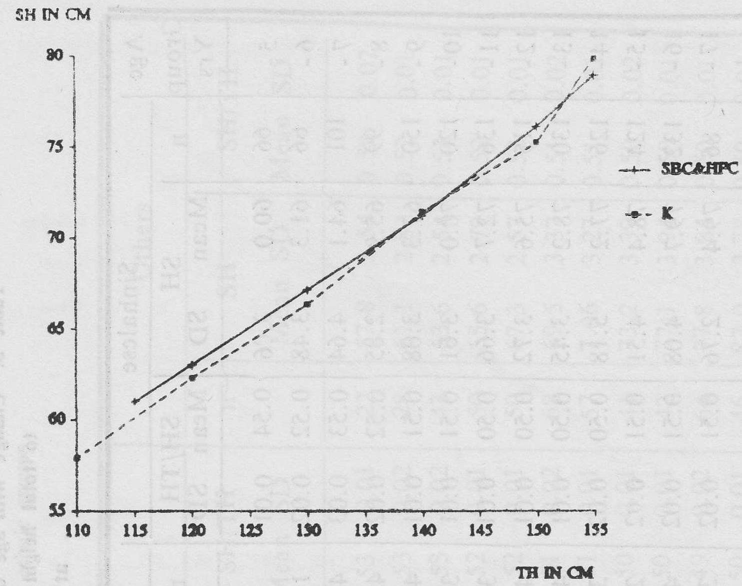

Fig. 3. Change in sitting height (SH) with total height (TH) of girls at the Convents (SBC + HFC) and the Kadawatha Schools (K).

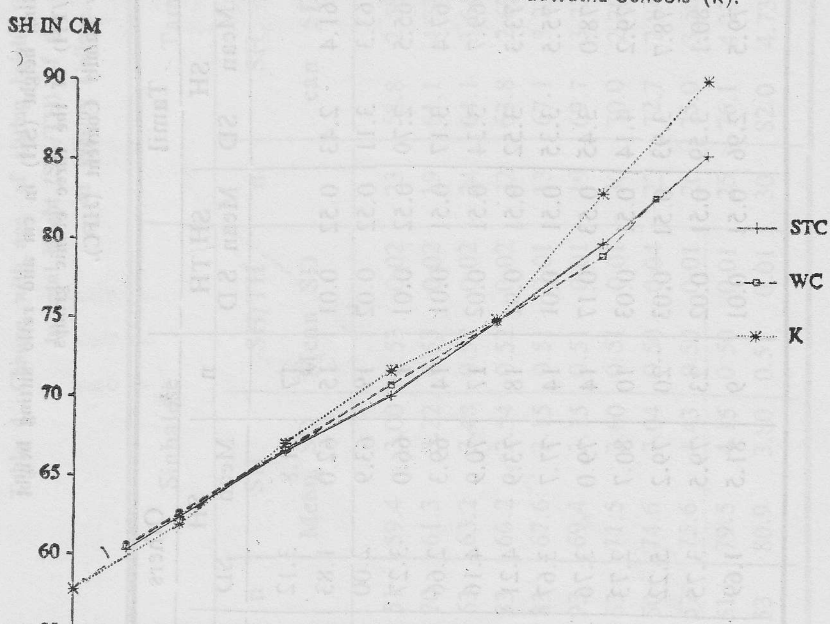

Fig. 4. Change in sitting height (SH) with total height (TH) of boys at St. Thomas' College (STC), Wesley College (WC) and the Kadawatha Schools (K).

Table 3. Change with age of sitting height (SH) in cm and ratio sitting height to total height (SH/TH) of the three ethnic groups at Holy Family Convent (HFC).

Age Group Yrs	Sinhalese					Tamil					Others				
	n	SH		SH/TH		n	SH		SH/TH		n	SH		SH/TH	
		Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD
5 -	66	60.0	3.06	0.54	0.01						17	61.8	3.12	0.55	0.02
6 -	66	61.3	3.48	0.52	0.02	16	61.4	2.43	0.52	0.01	15	62.0	1.83	0.53	0.01
7 -	101	64.1	4.64	0.53	0.03	42	63.3	3.11	0.52	0.02	19	63.9	2.00	0.53	0.02
8 -	99	65.9	2.85	0.52	0.02	42	65.5	2.70	0.52	0.01	17	66.0	3.27	0.52	0.01
9 -	150	67.3	3.08	0.51	0.01	43	67.4	3.17	0.51	0.01	14	69.3	2.66	0.51	0.01
10 -	120	70.0	3.61	0.51	0.01	34	69.7	3.34	0.51	0.02	17	70.9	4.16	0.51	0.01
11 -	136	72.7	3.66	0.50	0.01	30	73.3	3.52	0.51	0.01	18	73.9	4.21	0.50	0.01
12 -	115	75.6	3.72	0.50	0.01	42	75.5	3.35	0.51	0.01	14	77.7	3.67	0.51	0.01
13 -	130	78.2	3.45	0.50	0.01	46	78.0	3.45	0.53	0.17	14	79.0	3.76	0.51	0.02
14 -	126	77.2	5.18	0.50	0.02	39	79.2	4.14	0.51	0.03	10	80.7	2.73	0.51	0.01
15 -	124	78.4	4.51	0.51	0.02	27	78.7	3.93	0.51	0.03	20	79.2	5.22	0.51	0.02
16 -	132	79.7	4.08	0.51	0.02	40	80.1	3.59	0.51	0.02	23	79.5	3.75	0.51	0.01
17 -	86	79.4	2.76	0.51	0.02	35	79.5	2.96	0.51	0.01	9	81.5	1.69	0.51	9.01

Table 4. Change with age of sitting height (SH) in cm and ratio sitting height to total height (SH/TH) of the three ethnic groups at Wesley College (WC).

Age Group Yrs	Sinhalese					Tamil					Others				
	n	SH		SH/TH		n	SH		SH/TH		n	SH		SH/TH	
		Mean	SD	Mean	SD		ean	SD	Mean	SD		Mean	SD	Mean	SD
5 -	51	59.4	3.00	0.53	0.02	23	58.8	2.58	0.53	0.01	22	57.8	3.54	0.52	0.02
6 -	70	61.3	3.22	0.53	0.02	19	61.1	4.77	0.53	0.02	28	61.1	2.82	0.52	0.01
7 -	63	63.2	3.43	0.52	0.02	24	64.1	3.64	0.53	0.02	43	63.6	2.54	0.52	0.01
8 -	83	66.2	2.54	0.52	0,02	32	63.8	2.62	0.52	0.01	50	65.6	2.79	0.52	0.01
9 -	83	67.6	3.15	0.51	0.01	13	67.1	3.23	0.52	0.01	50	67.3	2.57	0.52	0.01
10 -	93	69.4	3.15	0.51	0.01	19	69.7	3.72	0.51	0.02	68	69.5	3.37	0.51	0.02
11 -	63	71.5	3.60	0.51	0.01	30	70.0	2.70	0.51	0.01	57	7.06	3.27	0.51	0.01
12 -	50	74.6	7.04	0.50	0.04	22	72.7	2.84	0.50	0.01	41	73.2	3.39	0.50	0.02
13 -	57	75.6	4.43	0.50	0.01	26	75.0	3.50	0.50	0.01	42	77.1	3.94	0.50	0.01
14 -	61	79.5	4.15	0.50	0.01	25	76.1	4.23	0.49	0.02	64	77.8	3.84	0.50	0.01
15 -	53	80.9	3.80	0.51	0.01	30	82.0	4.73	0.50	0.01	46	82.0	3.78	0.50	0.01

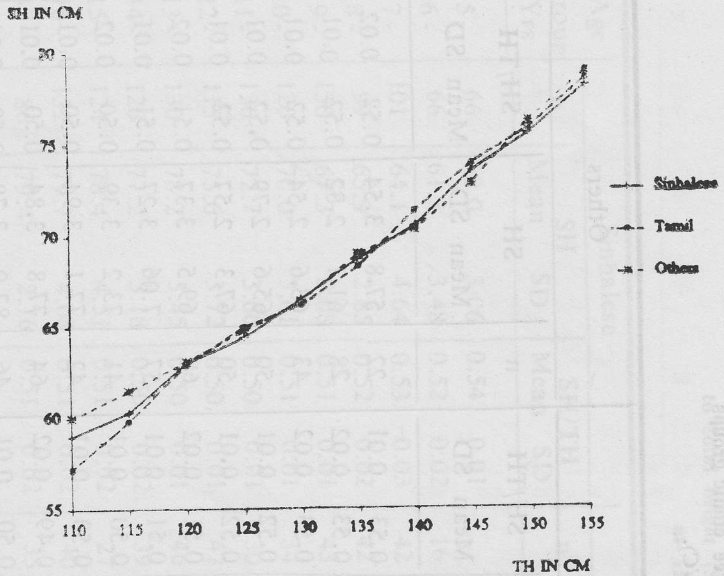

Fig. 5. Change of sitting height (SH) with total height (TH) of girls in different ethnic groups at the Holy Family Convent.

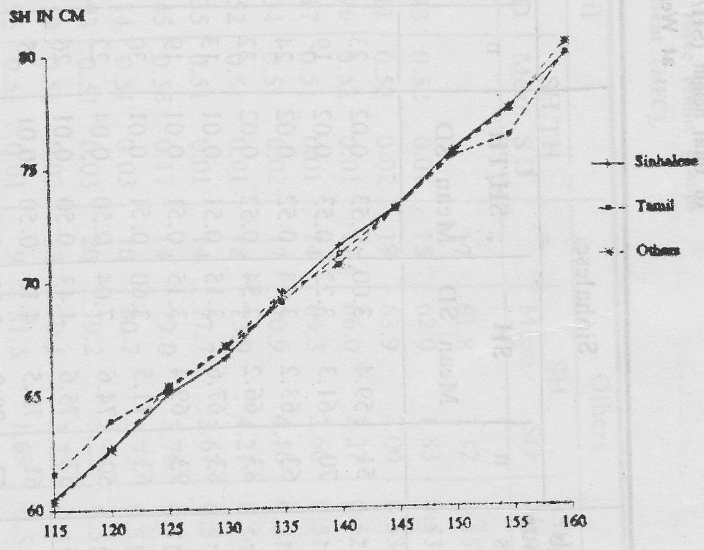

Fig. 6. Change of sitting height (SH) with total height (TH) of boys in different ethnic groups at Wesley College.

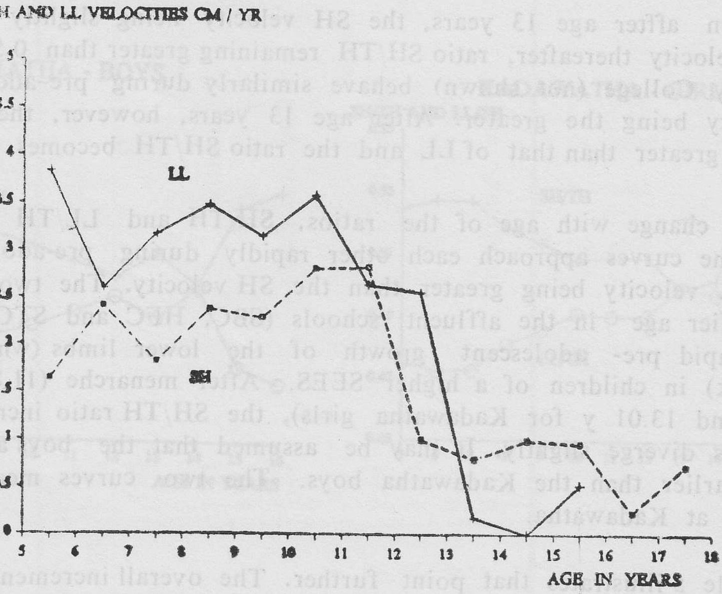

Fig. 7. Velocity curves for sitting height (SH) and leg length (LL) of girls of St. Bridget's and Holy Family Convents.

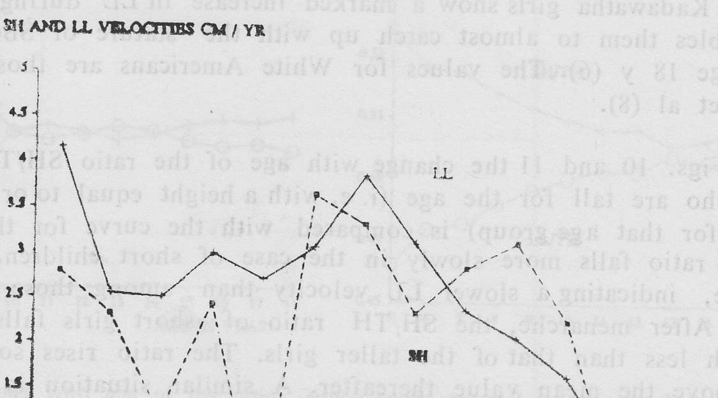

Fig. 8. Velocity curves for sitting height (SH) and leg length (LL) of boys at St. Thomas' College.

deceleration affter age 13 years, the SH velocity being slightly higher than the LL velocity thereafter, ratio SH/TH remaining greater than 0.5. The curves for Wesley College (not shown) behave similarly during pre–adolescence, the LL velocity being the greater. After age 13 years, however, the deceleration of SH is greater than that of LL and the ratio SH/TH becomes less than 0.5.

The change with age of the ratios, SH/TH and LL/TH is shown in Fig. 9. The curves approach each other rapidly during pre-adolescence due to the LL velocity being greater than the SH velocity. The two curves meet at an earlier age in the affluent schools (SBC, HFC and STC), indicating a more rapid pre- adolescent growth of the lower limbs (when compared with trunk) in children of a higher SEES. After menarche (11.8 y for SBC + HFC and 13.01 y for Kadawatha girls), the SH/TH ratio increases and the two curves diverge slightly. It may be assumed that the boys at STC reach puberty earlier than the Kadawatha boys. The two curves meet earlier at STC than at Kadawatha.

Table 5 illustrates that point further. The overall increment in LL (but not in SH) is socio - economic dependent during pre-adolescence. The stature at the beginning of adolescence is greater in affluent children due to the more rapid increase in LL. During adolescence the increment is similar among boys in the different groups and among American and affluent Sri Lankan girls. The Kadawatha girls show a marked increase in LL during adolescence, which enables them to almost catch up with the stature of SBC and HFC girls by age 18 y (6). The values for White Americans are those quoted by Martorell et al (8).

In Figs. 10 and 11 the change with age of the ratio SH/TH of affluent children who are tall for the age (i. e. with a height equal to or greater than the mean for that age group) is compared with the curve for those who are short. The ratio falls more slowly in the case of short children, during pre-adolescence, indicating a slower LL velocity than among those who are tall (Fig. 10). After menarche, the SH/TH ratio of short girls falls below 0 5, being much less than that of the taller girls. The ratio rises soon after and remains above the mean value thereafter. A similar situation is noted among the the boys (Fig. 11). The ratio plunges below the value 0.5 in the 9th year and stays below that level till about the 14th year.

Figs. 10 and 11 also indicate that the SH/TH ratio of the short children is less than that of the tall children for about one year after puberty, after which the ratio of short children again remains above the ratio of the taller children.

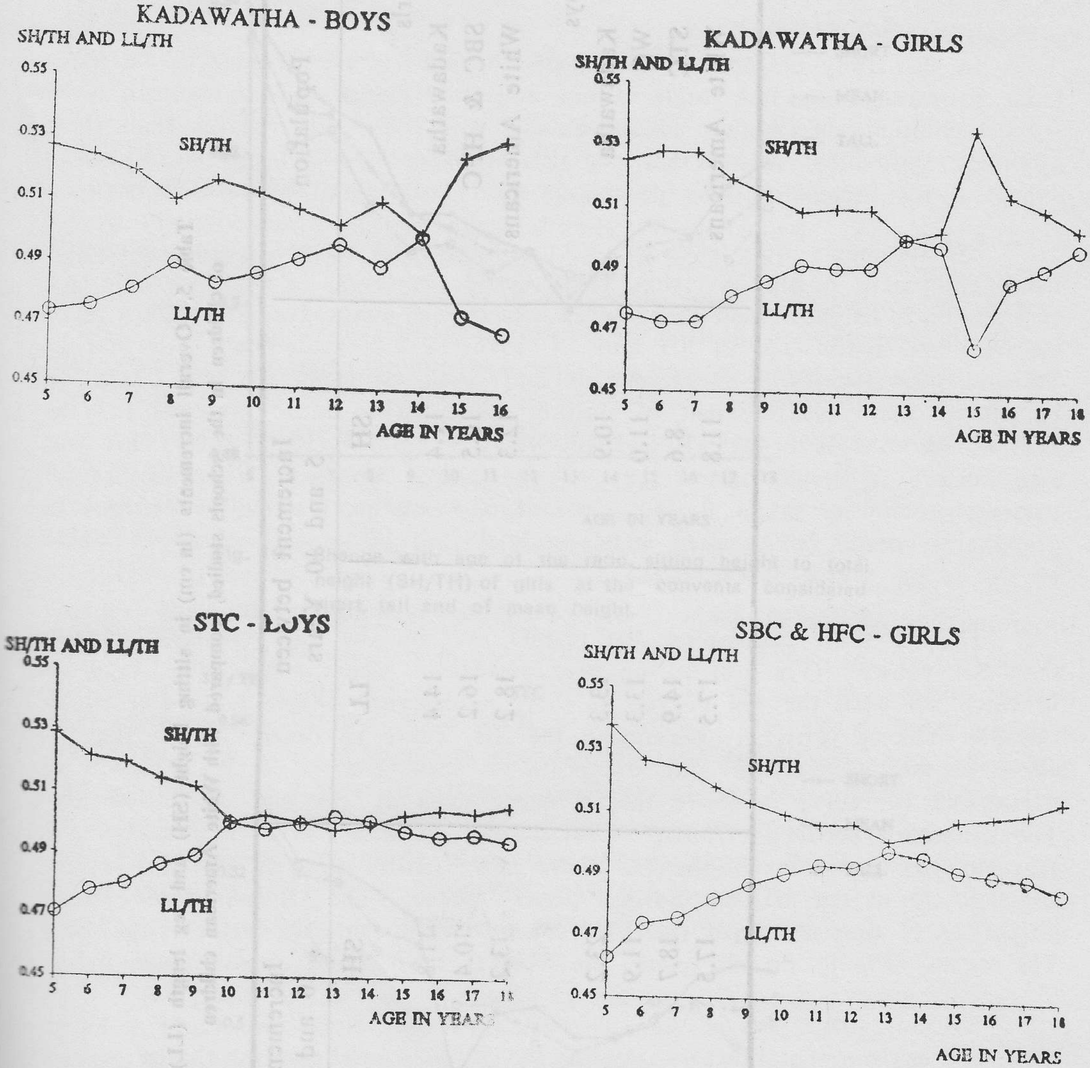

Fig 9. Change with age of the ratios, sitting height to total height (SH/TH) and leg length to total height (LL/TH).

Table 5. Overall increments (in cm) in sitting height (SH) and leg length (LL) of children in the schools studied, compared with White American children

Population	Increment between 5 and 10 Years		Increment between 10 and 18 Years	
	SH	LL	SH	LL
Girls				
Kadawatha	11.4	14.4	11.8	13.0
SBC & HFC	10.5	16.2	10.4	8.4
White Americans	12.3	18.2	13.2	9.2
Boys				
Kadawatha	10.9	13.3	23.2	16.3
WC	11.0	13.3	11.9	18.1
STC	8.6	14.9	18.7	16.8
White Americans	11.8	17.5	17.5	16.8

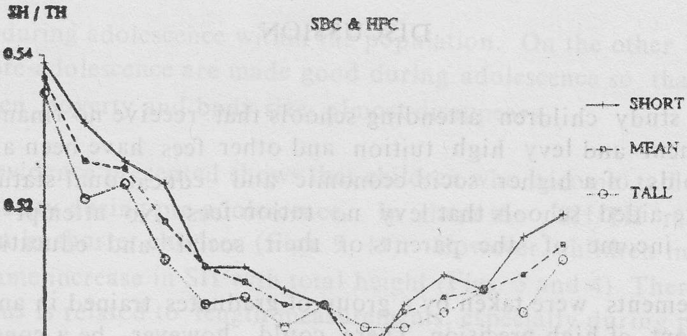

Fig. 10. Change with age of the ratio, sitting height to total height (SH/TH) of girls at the convents considered short, tall and of mean height.

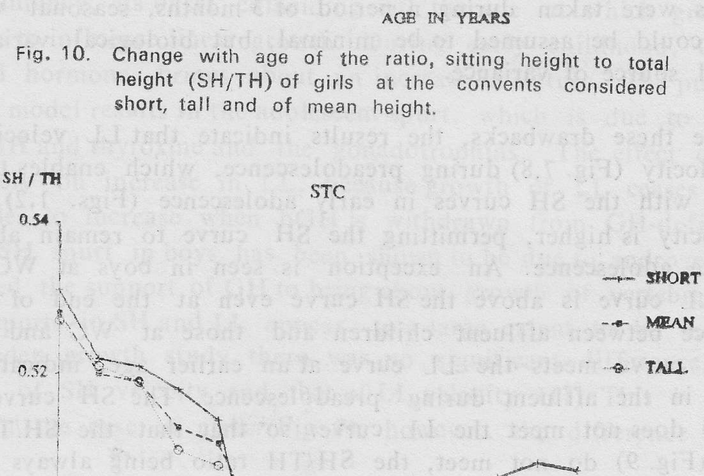

Fig. 11. Change with age of the ratio, sitting height to total height (SH/TH) of boys at St. Thomas' College, considered short, tall and of mean height

DISCUSSION

In this study children attending schools that receive no financial assistance from government and levy high tuition and other fees have been assumed to be from households of a higher socio-economic and educational status than those attending state-aided schools that levy no tution fees. No attempt was made to ascertain the income of the parents or their social and educational status.

Measurements were taken by a group of graduates trained in anthropometry, using equipment of high precision. There could, however, be a considerable lack of precision in height measurements. even with trained auxologists and sophisticated stadiometers. Estimation of SH and LL involves 2 measurements and that of SH and LL velocities, 4 measurements and such estimates are less likely to be precise than measurement of stature alone. This could account for the lack of smoothness in the SH and LL velocity curves (Fig. 7 & 8). This was also noticed in height and weight velocity curves reported earlier (6). As all measurements were taken during a period of 3 months, seasonal variations in growth rate could be assumed to be minimal, but biological variations could be an added source of variance.

Despite these drawbacks, the results indicate that LL velocity is greater than SH velocity (Fig. 7,8) during preadolescence, which enables the LL curves to catch up with the SH curves in early adolescence (Figs, 1,2), after which the SH velocity is higher, permitting the SH curve to remain above the LL curve in late adolescence. An exception is seen in boys at WC (Fig. 2) in whom the LL curve is above the SH curve even at the end of adolescence. The difference between affluent children and those at WC and Kadawtha is that the SH curve meets the LL curve at an earlier age, indicating a greater LL velocity in the affluent during preadolescence. The SH curve of affluent girls (Fig. 1) does not meet the LL curve, so that that the SH/TH and LL/TH curves (Fig. 9) do not meet, the SH/TH ratio being always above 0.5.

Stature, sitting height and subischial leg length are determined by both genetic and environmental factors. Among the environmental factors, the endocrines and nutrition are the most important. Children from households of a high SEES can be expected to have a higher nutritional status and live in more sanitary surroundings than the more deprived. They have a greater height and weight (6) and SH and LL (Tables 1 and 2) but differences are marked only during the pre-adolescent period (Table 3). Thus, poverty is related to stature in pre-adolescent children but not in adolescent children. It may be that relationships between poverty and stature are more easily detected during early childhood, such relationships being obscured during adolescence by the great variability in growth and

DISCUSSION

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The evidence presented shows that children who become tall are those with a high LL velocity during pre-adolescence. In them the SH/TH ratio falls more rapidly than in shorter children (Figs. 9, 11). However, children in all the schools show the same increase in SH with total height (Figs. 3 and 4). Therefore, although poverty status is related to length measurements, especially during pre-adolescence, neither poverty nor ethnicity (Figs. 3, 4, 5, 6) have any influence on the relative proportions. These observations are consistent with the view expressed by Tanner (9) that, in response to malnutrition, size is sacrificed and shape is preserved.

In the ICP model proposed by Karlberg and colleagues (10) to describe data on growth, the childhood component of growth begins to exert its effect towards the end of infancy, its onset coinciding with the age at which growth hormone (GH) begins to influence linear growth. During early childhood, GH, aided by the thyroid hormone, brings about an increase in stature. The puberty component of the model results in the adolescent spurt, which is due to the combined action of GH and thyroxine and the gonadotrophins. The effect of GH is probably entirely on increase in LL, because growth of LL ceases while that of SH continues to increase when hGH is withdrawn from GH-deficient children (11). The SH spurt in boys has been shown to be due to androgens (12) which do not need the support of GH to bring about growth of vertebral bodies (11). Although spurts in SH and LL appear, to a large extent, to be independent, in the Harpenden growth study there was no significant difference between the peak value of SH velocity and that of LL velocity (11). This is also indicated in Fig. 8. In the case of girls (Fig 7), however, the difference is larger.

Adequacy of intake of energy, protein and nutrients such as calcium will influence the growth of limbs as well as of vertebral bodies. During pre-adolescence, however, limds are growing faster and undernutrition will retard LL more than SH, which accounts for the fact that the overall increment in LL is more socio-economic dependent than the increment in SH during pre adolescence (Table 3). Children at Kadawatha are further disadvantaged as the prevalence of iodine deficiency is greater in the Gampaha District (in which Kadawatha is situated) than in the Colombo District (13). Both the socio-economic status (14) and iodine deficiency and, therefore, thyroxine deficiency, could also delay the onset of the childhood component. Children with late onset of this component show inadequate catch-up growth (14).

According to Karlberg (15) the dramatic change in body proportions during pre-adolescence is due to the greater influence of the childhood component on LL than SH, while after puberty LL stops growing sooner than SH. Early pubertal maturation in the females at SBC and HFC could therefore be the reason for LL being shorter than SH during late adolescence and the SH/TH ratio being less than 0.5.

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