Ceylon J. Med. Sci. 33 (*No.* 1, *June*) 1990, *pp.* 1—14.

AUXOLOGY OF SRI LANKAN CHILDREN AGED 5 TO 18 YEARS: 2. QUETELET'S BODY MASS INDEX

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SUMMARY. Quetelet's index (W/H^2) has been calculated from heights and weights of 8606 children attending schools in and around the city of Colombo.

BMI was found to be independent of gender, between 5 and 9 years. During adolescence, BMI is greater in girls. Between 5 and 18 years BMI increases with age, the increase during pre-adolescence being small. The increment in BMI is socio-economic dependent during pre-adolescence but not during adolescence.

Among the upper socio-economic groups BMI has increased during the period 1936-1988. However among the lower socio-economic group, BMI of children between 5 and 9 years was higher in 1936. The fall in BMI seen in 1988 among the deprived sections of the population is probably due to the removal of food subsidies and the adoption of an open-market economy in 1978, resulting in price increases.

BMI of affluent Sri Lankan children is comparable to the values of Hong Kong born Chinese children, but markedly different from those of affluent Indian girls in New Delhi and Irish and American (NCHS) populations.

Values for BMI less than 13.5 will include more than 90% of pre-adolescent children with low weight for height and about 29% of children with adequate weight for height. A BMI less than 15.0 will include about 80% of early adolescents with low weight for age as well as 16% of those with adequate weight for age. In the late adolescent group (13 to 18 years) about 98% of children with adequate weight for age and about 16% with adequate height for age have BMI greater than 15.0.

Key Words : BMI, Socio-economic status, Secular change, Nutritional status.

INTRODUCTION

Several attempts have been made to adjust body weight for height, in order to derive a height-free measure of obesity. The first index suggested was that of Quetelet (1869), who observed that the weights of adults were proportional to their heights squared: i.e. W/H^2 was constant for people of normal build. In 1972 Keys et al. (1) named this ratio the body mass index (BMI). Quetelet's index is now accepted as a convenient and reliable indicator of obesity (2), in preference to several others suggested. BMI is also used for identifying at-risk groups with regard to degenerative diseases likely to be related to obesity (3, 4). Keys (5) pointed out that, among middle-aged Americans, mortality risks are higher in those whose BMI is below 20. In a prospective study of a Norwegian population, on the relationship of BMI to mortality risks, Waaler (6) found that, in persons over 50 years of age, the risk of mortality increased when their BMI was above 29 or below 19.

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Few studies have tried to identify cut-off points of BMI which are comparable to other indicators of malnutrition among children. In a study of Indian children between 1 and 5 years of age Rao and Rao (7) found that increase in height and weight ran parallel to the frequency with which BMI was maintained above 15. The highest incidence of energy protein malnutrition was observed in children whose BMI was consistently below 15. They suggested that a BMI of 15 be used to differentiate the well-nourished from the malnourished pre-schoolers. Sukkar et al. (8) reported that, among Sudanese children, the cut-off point varied between different age groups. A BMI of 14.5 indicated a weight for age below 75% of the Harvard standard for those below 15 years, and, for those between 5 and 9 years, the value was 13.5.

The aims of the present study were to :

1. determine the influence on BMI of age, gender and socio-economic-educational status.
2. look for any secular changes in BMI of Sri Lankan children,
3. compare Sri Lankan values with those of other populations,
4. identify a cut-off point of BMI as an indicator of malnutrition.

SUBJECTS AND METHODS

Boys attending St. Thomas' College, Mt. Lavinia and Kollupitiya (denoted as STC). Wesley College (WC) and 3 schools at Kadawatha, and girls attending two convents in the city of Colombo, St. Bridget's and Holy Family Convents (SBC & HFC) and three schools at Kadawatha, formed the study population. The schools selected, the equipment used and precautions taken when measuring heights and weights have been described earlier (9). Quelelet's body mass index (W/H^2 or BMI) for each child was calcualted from his/her weight and height.

RESULTS

Tables 1 and 2 indicate the BMI (mean and s.d.) for each age group, for girls and boys respectively. In each age group, the affluent girls at SBC and HFC have higher BMIs than those at Kadawatha, who hail from households of a lower socio-economic-educational level. The BMI of affluent girls reach a plateau at age 16 and that of Kadawatha girls, a year later (Table 1). Affluent boys (STC) have higher BMIs than those at WC and in the Kadawatha schools (Table 2) between 5 and 16 y, and reach a plateau at age 16, whereas the BMI of boys at WC reach a slightly higher value a year later. Therefore, BMI is socio-economic dependent.

TABLE 1. BMI (mean and s.d.) of girls at St. Bridget's and Holy Family (SBC / HFC) convents and Kadawatha schools

Age yrs.	SBC & HFC			Kadawatha		
	n	Mean	s.d.	n	Mean	s.d.
5—	174	14.2	1.96	29	13.2	1.03
6—	245	14.1	2.06	29	13.4	1.21
7—	333	14.7	2.58	47	13.1	0.88
8—	285	14.9	2.58	44	13.2	1.03
9—	306	15.3	2.40	30	13.6	0.99
10—	303	16.1	3.28	49	14.3	1.55
11—	338	16.6	3.22	51	15.1	1.66
12—	318	17.5	3.20	29	15.6	1.93
13—	305	18.6	3.36	22	15.8	2.14
14—	286	19.3	4.32	39	16.9	2.46
15—	208	18.9	3.06	69	15.5	2.39
16—	284	19.2	2.72	9	17.8	2.35
17—	243	19.2	2.83	17	18.5	1.83
18—	144	19.3	3.02	17	18.0	2.00

TABLE 2. BMI (mean and s.d) of boys at St. Thomas' College (STC), Wesley College and Kadawatha schools

Age yrs.	STC			Wesley			Kadawatha		
	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.
5—	108	14.6	1.77	96	14.3	1.14	33	13.6	1.00
6—	215	14.3	1.82	117	14.0	1.41	31	13.2	1.22
7—	255	14.8	2.03	130	14.0	1.34	42	13.2	1.30
8—	176	15.2	2.31	165	14.6	2.08	39	13.4	1.56
9—	170	15.0	2.32	146	14.7	2.20	36	14.0	0.88
10—	228	16.5	3.13	180	14.8	2.54	49	13.7	0.96
11—	176	16.8	3.30	150	15.5	2.23	60	14.8	1.57
12—	245	17.0	3.59	113	15.7	2.49	24	14.8	1.80
13—	175	16.9	3.27	134	16.0	2.48	21	14.9	1.45
14—	221	17.2	3.06	151	16.6	2.25	47	16.2	2.99
15—	146	17.6	3.65	127	17.4	2.13	62	14.8	2.35
16—	107	19.3	3.73	52	18.4	0.25	16	15.0	1.79
17—	87	18.8	3.14	25	19.4	1.77			
18—	73	19.2	2.55	24	20.2	3.23			

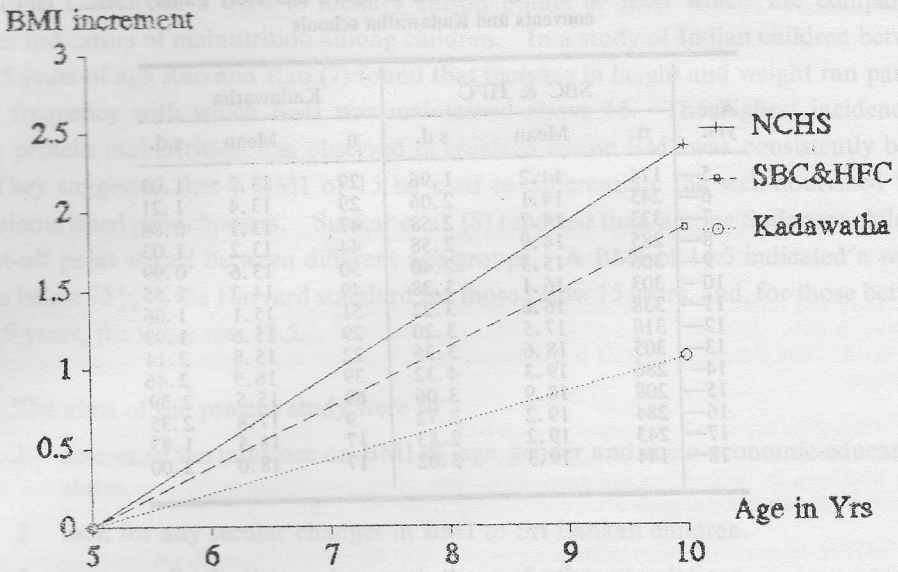

Fig. 1a. Overall increment in BMI of girls during pre-adolescence.

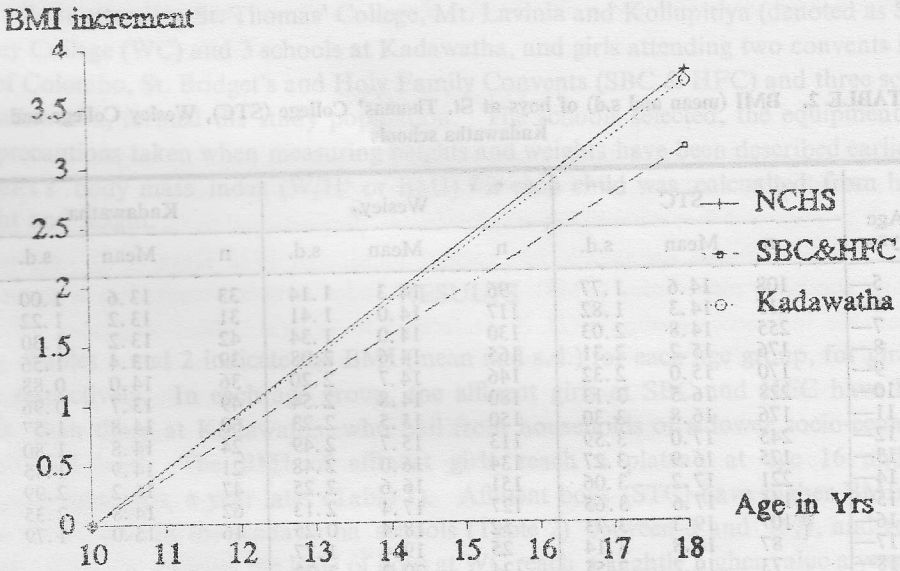

Fig. 1b. Overall increment of BMI of girls during adolescence.

In Figs. 1 and 2 the increment in BMI between 5 and 10 years is compared with the increment between 10 and 18 y. Whereas the affluent girls have a higher increment than the Kadawatha girls during childhood, during adolescence there is a greater increase in the BMI of Kadawatha girls. In the case of boys too, between ages 5 and 9 y the BMI increment is socio-economic dependent.

The Kadawatha schools were found to have more under-nourished children than the other schools studied (9). Figs. 3 and 4 compare the BMI of children considered "normal" according to the Waterlow classification of nutritional status. At each age group there is a marked influence of socio - economic - educational status on BMI. Analysis of variance shows that the differences are highly significant ($p<0.001$), for both boys and girls. The mean BMI at age 9 y is significantly higher than that at age 5 y ($p<0.05$ for SBC & HFC, and $p < 0.01$ for STC). Therefore BMI is age - dependent, the increment being very slight between 5 and 9 years and more marked during adolescence (Figs. 5 and 6).

On the other hand, comparison of SBC & HFC with STC (Fis. 5) shows (that BMI is independent of gender, between age 5 and 9 y, the values for the two groups of schools showing no significant differences. During adolescence, however, the differences between boys and girls are marked. Similarly the BMI of Kadawatha boys and girls are almost the same till age 11, after which the BMI of girls is higher (Fig. 5).

Figs. 6 and 7 compare the BMI of children in the present study with BMI calculated from mean weights and heights recorded by Nicholls in 1936 (10). The BMI of affluent girls in 1988 (SBC & HFC) is higher than that of girls of similar socio - economic status studied by Nicholls (SS in Fig. 6). The Kadawatha girls have a higher BMI than girls in the vernacular schools of 1936 (VS in Fig. 6), between age 10 and 18 y. But the BMI in 1988 is much lower than that in 1936, between 5 and 9 y. Below age 6 even SBC and HFC girls have a lower BMI than their counterparts of 50 years ago. Thus, among girls at lower socio - economic levels, there has been a lowering of BMI in early childhood and an increase in BMI during adolescence.

Affluent boys of 1988 (STC) have a higher BMI than affluent boys of Royal College in 1936 (RC in Fig. 7) below age 14 y. After puberty the BMIs are similar. Between Wesley College boys of 1988 and boys of similar socio - economic status studied in 1936 (SS in Fig. 7) there has been an increase in BMI, after age 9 y. Fig 7 also shows a different pattern among boys of a lower socio - economic status (Kadawatha and VS in Fig. 6). While the BMIs are lower in 1988 than in 1936, between ages 5 and 9 y, during adolescence the values for 1988 tend to be higher.

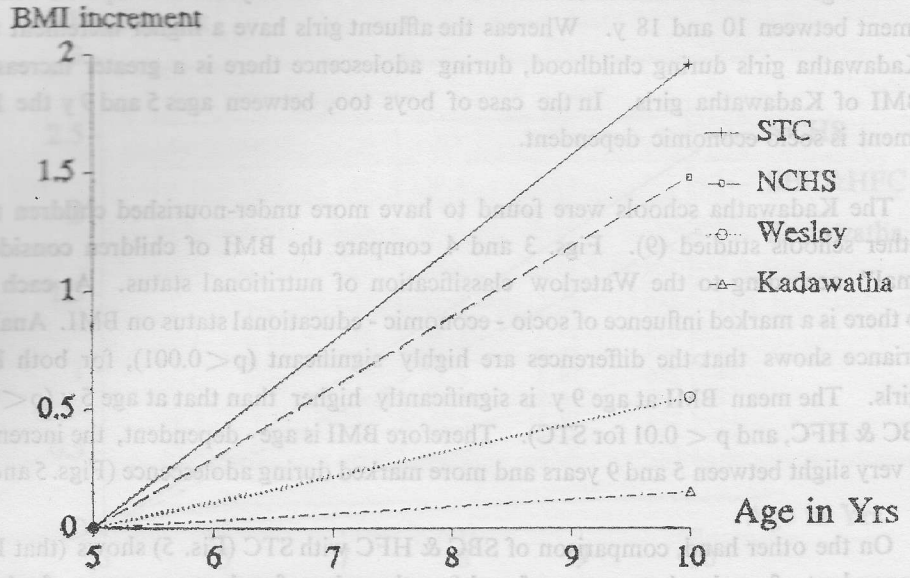

Fig. 2a. Overall increment of BMI of boys during pre-adolescence.

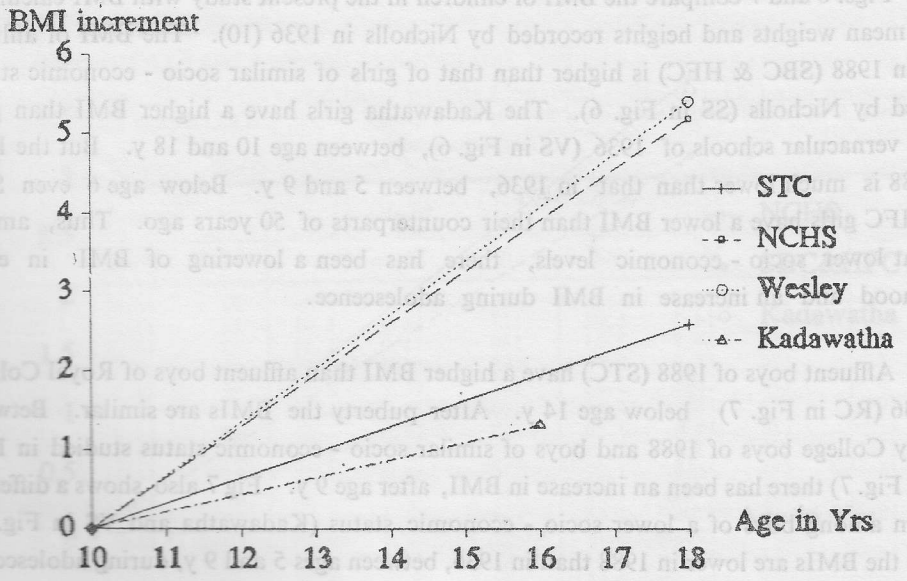

Fig. 2b. Overall increment of BMI of boys during adolescence.

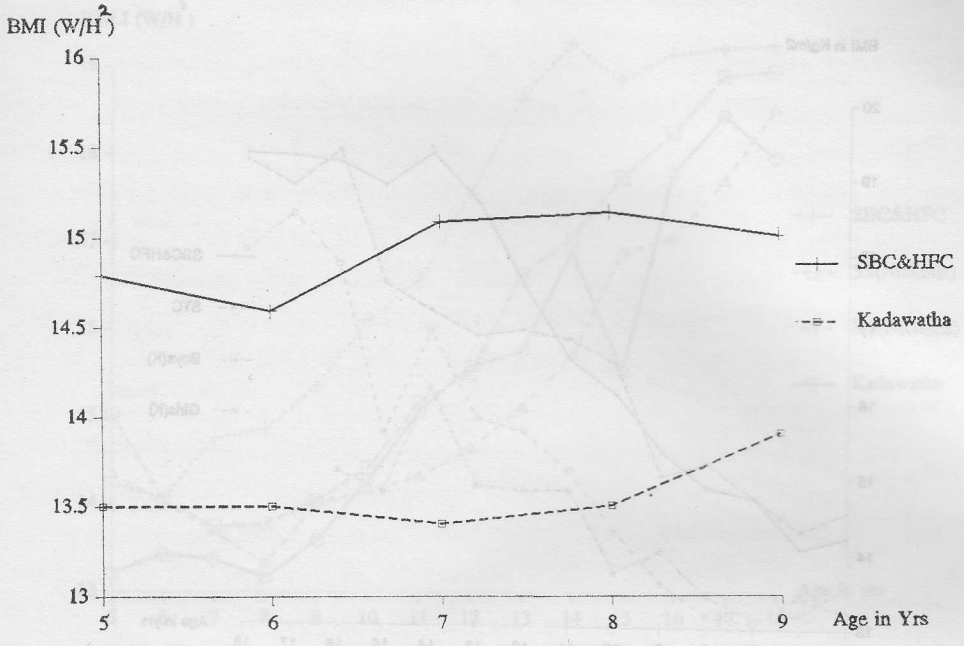

Fig. 3. Change of BMI with age during pre-adolescence, of affluent (SBC+HFC) and less affluent (Kadawatha) girls.

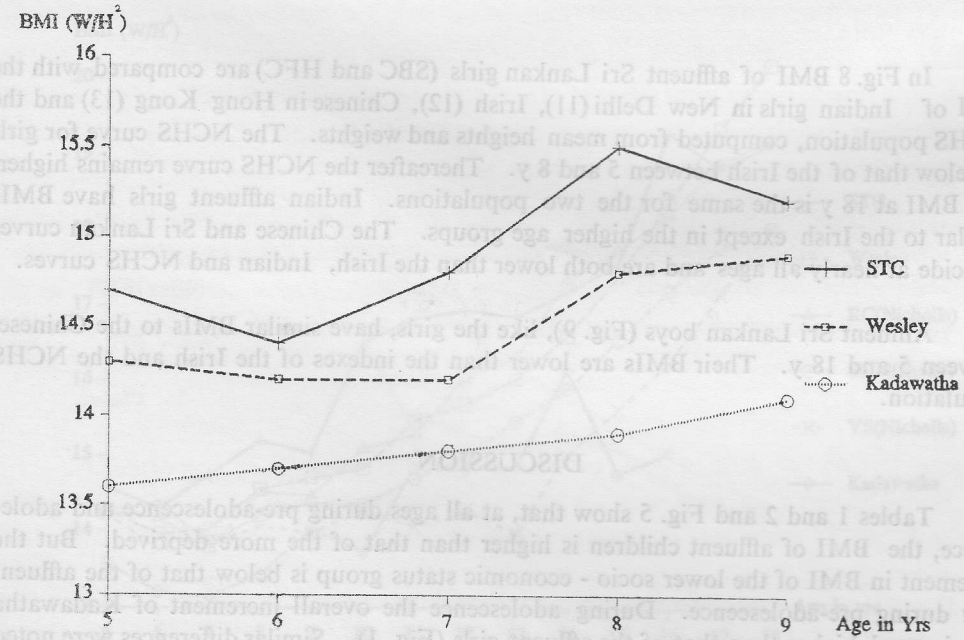

Fig. 4. Change of BMI with age during pre-adolescence, of affluent (STC) and less affluent (Wesley and Kadawatha) boys.

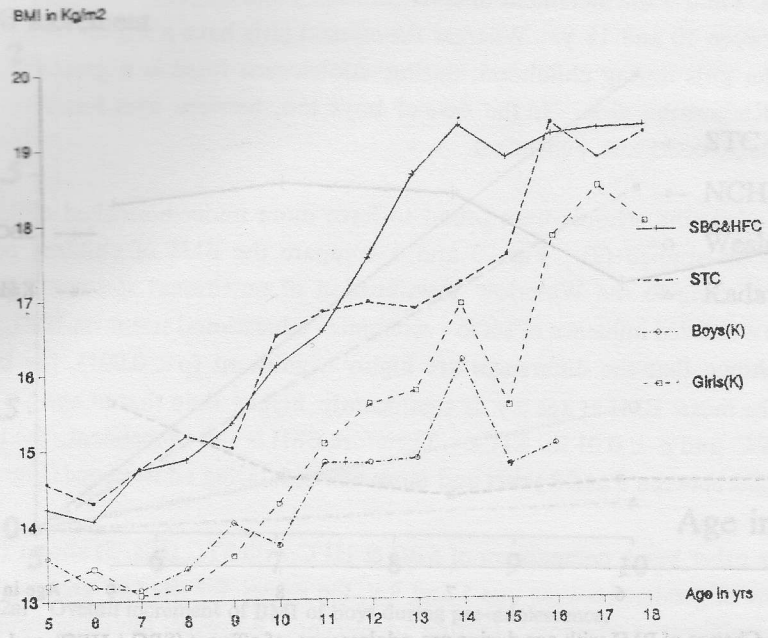

Fig. 5. Comparsion of BMI of girls and boys during pre–adolescence and adolescence.

In Fig. 8 BMI of affluent Sri Lankan girls (SBC and HFC) are compared with the BMI of Indian girls in New Delhi (11), Irish (12), Chinese in Hong Kong (13) and the NCHS population, computed from mean heights and weights. The NCHS curve for girls is below that of the Irish between 5 and 8 y. Thereafter the NCHS curve remains higher. The BMI at 18 y is the same for the two populations. Indian affluent girls have BMIs similar to the Irish except in the higher age groups. The Chinese and Sri Lankan curves coincide at nearly all ages and are both lower than the Irish, Indian and NCHS curves.

Affluent Sri Lankan boys (Fig. 9), like the girls, have similar BMIs to the Chinese, between 5 and 18 y. Their BMIs are lower than the indexes of the Irish and the NCHS population.

DISCUSSION

Tables 1 and 2 and Fig. 5 show that, at all ages during pre-adolescence and adolescence, the BMI of affluent children is higher than that of the more deprived. But the increment in BMI of the lower socio - economic status group is below that of the affluent only during pre-adolescence. During adolescence the overall increment of Kadawatha girls is much higher than that of the affluent girls (Fig. 1). Similar differences were noted in increments of heights and weights before and during adolescence (9).

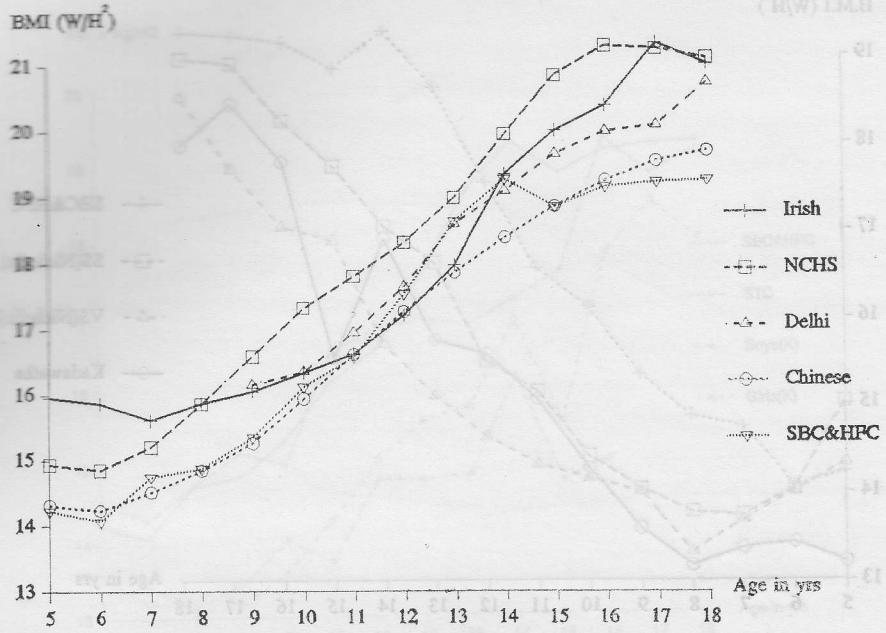

Fig. 8. Comparison of BMI of affluent Sri Lankan girls with BMI of girls in Delhi, Hong Kong, Ireland and North America (NCHS).

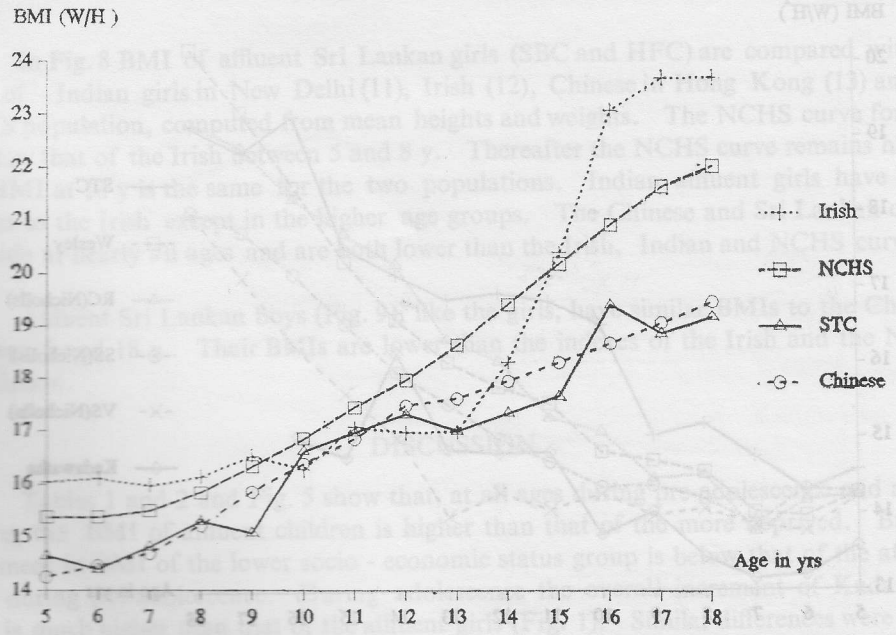

Fig. 9. Comparison of BMI of affluent Sri Lankan boys with BMI of boys in Hong Kong, Ireland and North America (NCHS).

However, the increment of BMI of the Kadawatha boys remains below that of STC and WC boys during adolescence as well as during pre-adolescence.

Comparison of BMI of children adepuately nourished, according to the Waterlow classification, shows that the BMI between age 5 and 9 years is significantly higher among the affluent children (Fig. 3 and 4). BMI is also age-dependent. When the affluent children are compared (Fig. 5) it is seen that, between ages 5 and 10 years, BMI is independent of gender. The BMI of girls becomes greater than that of boys during adolescence.

Among the more affluent children there has been an increase in BMI during the past 50 years (Figs. 6 and 7) in most age groups between 6 and 18 years. The picture is different among children of a lower socio-economic status. Their BMI between ages 5 and 9 years was higher in 1936 than in 1988, whereas the BMI of adolescents was higher in 1988 than in 1936. The adolescents of 1988 would have been pre-schoolers between 1970 and 1978. During 1972-1975 there were food shortages in Sri Lanka and many other developing countries due to a world-wide drought. Despite this calamity children born during that time appear to have attained a higher nutritional status than those born after 1978, due, probably, to the distribution of subsidized rations to the whole population. In 1978 these subsides (which had been introduced after World War II) were removed and a food stamp scheme inaugurated, to assist the lower income groups. The assistance rendered by the food stamp scheme had only a small impact on expenditure on food (14) which rose rapidly due to the adoption of an open market economy, and a high inflation rate. Between 1978 and 1988 there was a fall in the nutritional status of pre-scholers of lower income groups in all three sectors, urban, rural and estate (15). The effects of economic policies pursued between 1978 and 1988 are to be seen on the pre-adolescent children of the present day.

Comparison of BMIs of affluent Sri Lankan children with the NCHS population (Figs. 8 and 9) shows that the NCHS curves are far above the Sri Lankan curves, which approximate with curves for Chinese in Hong Kong (13). The differences between Sri Lankan and NCHS curves for BMI vs. age are mainly due to the lower body weights of Sri Lankan children (9). This supports the earlier conclusion that NCHS weight for height values for children between 5 and 9 years of age are not applicable to Sri Lankan children.

TABLE 3. BMI of children in the study considered undernourished according to the Waterlow classification

Age y	Height for Age <90% NCHS median				Weight for Age < 80% NCHS median				Weight for height < 80% NCHS median			
	n	<13.5	13.5—15.0	>15,0	n	<13.5	13.5—15.0	—15,0	n	<13.5	13.5—15.0	<15.0
5— 9	98	54	28	16	876	627	236	13	352	323	27	2
		55.1%	28.6%	16.3%		71.6%	26.9%	1.5%		91.8%	7%	6%
10—12	185	48	69	68	964	290	489	185	—	—	—	—
		26.0%	37.3%	36.7%		30.0%	50.8%	19.2%				
13—18	322	23	66	233	1587	124	328	1135	—	—	—	—
		7.1%	20.5%	72.4%		7.8%	20.7%	71.5%				

Table 3 analyses the distribution of BMI of children considered undernourished according to criteria used in classifying nutritional status. In the 5 to 9 year group, the cut-off point of 13.5 for BMI, suggested by Sukkar et al (8) for pre-adolescent children, will include more than 90% of those with a low weight for height (the "wasted", according to the Water low classification). NCHS weight for height values are not used for assessment of nutritional status of adolescents. During early adolescence (10 to 12 y, inclusive) a cut-off point of 15.0 for BMI will include about 80% of children with low weight for age. For late adolescents (13 to 18 y) a BMI of 15.0 is less useful, about 70% of undernourished children having a BMI greater than 15.0. BMI is a poor indicator of those with low height for age.

TABLE 4. BMI of children considered normal according to the Waterlow classification of nutritional status

Age y	Height for Age > 90% NCHS median				Weight for Age > 80% NCHS median				Weight for height > 80% NCHS median			
	n	<13.5	13.5—15.0	<15.0	n	<13.5	13.5—15.0	<15.0	n	<13.5	13.5—15.0	<15.0
5—93	3186	1118	1236	832	2408	545	1028	835	2932	849	1237	846
		35.1%	38.8%	26.1%		22.6%	42.7%	34.7%		29.0%	42.2%	28.8%
10—12	2127	261	618	1248	1348	19	198	1131	—	—	—	—
		12.3%	29.0%	58.7%		1.4%	14.7%	83.9%				
13—18	2826	106	280	2240	1562	6	18	1538	—	—	—	—
		3.7%	10.0%	86.3%		0.4%	1.2%	98.4%				

Table 4 shows the distribution of BMI of children considered "normal" according to the Waterlow classification. In the 5 to 9 year groups, 29% of children with a weight for height>80% of the NCHS reference values have a BMI of less than 13.5. Thus, about one-third of normal children will be included among the undernourished if a BMI of 13.5 is used by itself to differentiate between the undernourished and the well-nourished among pre-adolescents. Among early adolescents, using a BMI of 15.0 as a cut-off point will give about 16% false-positives.

A BMI of 15.0 is of greater use in the 13 to 18 y group, less than 2% of those with weight for age>80% NCHS values and less than 14% of those with height for age>90% of NCHS values being among the false-positives.

Thus, a BMI of 13.5 is useful in assessing the nutritional status of pre-adolescents. A value of 15.0 could be used for these over 13 years of age.

ACKNOWLEDGEMENTS

We thank the following for assisting with anthropometric measurements of the children: M. Arsekularatne, R. Godawatta, D. Hersi, N. Iqbal, S. Jayasuriya, R. Kandiah, C. Kularatne, V. Liyanage, A. Ratnayake, A. Senadeera, and N. Wickremasinghe.

We also thank the Principals and children of the eight schools for their co-operation and Miss Dayaneetha Jayasinghe for secretarial assistance.

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