The National Center for Health Statistics reference and the growth of Indian adolescent boys[1,2]

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ABSTRACT

Background: Few studies describing the growth of adolescents exist because of the difficulties in interpreting anthropometric data in this age group.

Objective: We describe the growth of adolescent boys from West Bengal, India, and assess the adequacy of using the National Center for Health Statistics (NCHS) reference data.

Design: A cross-sectional anthropometric survey was conducted in 818 Bengali boys from middle-class families. Anthropometric measurements were taken on each subject's birthday (±3 d) by use of standard measuring techniques. The NCHS reference data on height and body mass index (BMI) were used to estimate age-specific prevalences of stunting, thinness, and overweight. BMI was also assessed by using British, Dutch, and French reference data. The biological parameters of the adolescent growth spurt were estimated by using the Preece-Baines growth model.

Results: With use of the 5th percentile of the NCHS reference data, the prevalence of thinness was ≈5 times (50.5%) that of stunting (11.2%). The median curves of the 3 European references lay between the Indian and NCHS samples and also yielded high prevalences of thinness when applied to the study sample. The prevalence of being at risk of overweight was low (4.2%). Mean age at peak height velocity was 13.0 y and peak height velocity was 7.0 cm/y.

Conclusions: The NCHS reference data seem inadequate for this sample. Consideration should be given to developing appropriate reference data based on healthy adolescent populations from different ethnic groups. Issues of maturation-related variation in assessing growth during adolescence should be given particular attention. *Am J Clin Nutr* 2001;74:248–53.

KEY WORDS Growth, anthropometry, adolescents, puberty, maturation, body mass index, India, boys, National Center for Health Statistics reference

INTRODUCTION

Little is known about the nutritional status of adolescents in both developed and developing countries. One reason for this gap in knowledge is the lack of an internationally agreed on method for assessing nutritional status during this period of life. As in other stages of the life cycle, in adolescence nutritional status is best assessed by using anthropometric measurements. However, the assessment of over- and undernutrition during adolescence is complicated by important changes in body composition, in particular during the puberty-related growth spurt. As a result, much less is known about anthropometry in adolescents than in younger and older age groups. Rapid changes in somatic growth, problems of dealing with variations in maturation, and the difficulties involved in separating normal variations from those associated with health risks have deterred the gaining of scientific knowledge relating adolescent anthropometry with determinants and health outcomes (1).

In 1993 a World Health Organization (WHO) Expert Committee made provisional recommendations for the interpretation of anthropometric data during adolescence (2). The committee recommended the use of the National Center for Health Statistics (NCHS) reference population to be consistent with the currently advocated international growth reference for children. These reference data were proposed for identifying individuals and populations at risk, assessing response to interventions, and facilitating international comparisons.

To assess stunting during adolescence, the indicator and cutoff are the same as used in early childhood, ie, <3rd percentile or <-2 z scores of height-for-age. Body mass index (BMI) in relation to age, or BMI-for-age, was recommended as the best anthropometric indicator of thinness and overweight during adolescence. The recommended cutoffs are <5th and ≥85th percentile for thinness and overweight, respectively. Because of the lack of evidence for the universal applicability of these data, however, the committee expressed caution in the use of the NCHS reference data and recommended that research be conducted to evaluate the suitability of these US reference data for assessing adolescent growth worldwide. Of particular concern were the upper percentile elevations and skewness of the NCHS values.

We describe the growth of adolescent Bengali boys and asses the adequacy of using the NCHS reference population to evaluate the nutritional status of Indian adolescents. Biological

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TABLE 1
Selected characteristics of the study population[1]

Variable	Frequency
	%
Education of father	
Below matriculate (<10 y of schooling)	18.2
Matriculate to below graduate (10–14 y of schooling)	44.9
Graduate and above (≥14 y of schooling)	36.9
Occupation of father	
Professional, managerial, or administrative	24.1
Clerical or sales	29.6
Manual worker and other	46.3
Education of mother	
Below matriculate (<10 y of schooling)	36.3
Matriculate to below graduate (10–14 y of schooling)	44.1
Graduate and above (≥14 y of schooling)	19.6
Occupation of mother	
Professional, managerial, or administrative	2.5
Clerical or sales	1.0
Manual worker and other	1.5
Housewife	95.0
Per capita expenditure (rupee/mo)	
<250	58.2
250–500	39.6
>500	2.2
Number of siblings	
None	23.3
1	46.8
≥2	29.9
Caste	
Low	17.1
Middle	25.3
Upper	57.6

[1] $n = 818$.

parameters of the adolescent growth spurt in this population are also reported.

SUBJECTS AND METHODS

The subjects included in this analysis were participants of a cross-sectional study comprising 856 Bengali boys aged 7–16 y. This anthropometric survey was carried out from April 1982 through September 1983 in a high school located within one of the densely populated areas of north Calcutta. The students were mostly middle-class Hindu Bengalis who belonged to upper castes such as Brahmin, Baidya, and Kayastha and some lower castes. Thus, this was not a representative sample of all Bengali boys aged 7–16 y. Information on the student's date of birth and the socioeconomic and demographic characteristics of the student's family were obtained from the parents with the cooperation of the school authorities. Data on per capita expenditure were used to assess the income level of the participating families.

Of the original sample, 38 boys were excluded during the measurements because of major illness or signs of physical deformity. The remaining 818 healthy subjects constituted the final sample. Twenty-six anthropometric measurements of each boy were taken by a single observer who followed the protocol of the International Biological Programme (3). Measurements were taken on the subject's birthday (±3 d); accordingly, the results presented here refer to exact age points (7.0 y, 8.0 y, etc). Dates of birth were verified by checking birth certificates. Height was recorded to the nearest centimeter by using an anthropometer rod. The boys were weighed with use of a lever-actuated balance to the nearest 0.5 kg while they wore light pants only.

The precision of the single observer was assessed by the technical error of measurement (TEM), calculated as the square root of the sum of squared differences between duplicate measurements, divided by 2 times the number of subjects measured (4). Duplicate measurements were taken 6 h apart on the same day. The observer's TEM values were 0.07 cm for height and 0.09 kg for weight, both of which are well below the maximum acceptable TEM reference values reported by Ulijaszek and Kerr (5). The TEM was established on the basis of measurements made of 21 subjects for height and 15 for weight.

BMI (kg/m^2) and height-for-age z scores were calculated for each individual. The NCHS reference data for height and BMI were used to estimate age-specific prevalences of stunting, thinness, and overweight according to the recommendations made by the WHO Expert Committee (2). In addition, the BMI of the Calcutta sample was assessed by applying as a basis for comparison the British (6), the Dutch (7), and the French (8) BMI-for-age reference data. The BMI analysis is limited to children aged 9–16 y ($n = 658$) because the reference data recommended by the WHO Expert Committee start at 9 y of age (2).

Biological variables of the adolescent growth spurt were estimated by fitting Preece-Baines model 1 curves (9) to the mean annual height values from ages 7–16 y. The Preece-Baines growth model is a family of curves that conform to the shape of the human growth curve. The model is most often used to analyze longitudinal records on individuals, but can also be applied to cross-sectional data from population surveys (10–14). All analyses and curve-fitting procedures were performed at the Indian Statistical Institute of Calcutta by using the BMDP statistical package (15).

RESULTS

The socioeconomic and demographic characteristics of the study sample are presented in **Table 1**. Eighty-two percent of the fathers and 64% of the mothers had ≥10 y of schooling. Of those, ≈37% of the fathers and 20% of the mothers completed graduate level or above (ie, ≥14 y of schooling).

Occupations of the fathers were diverse. About 24% of the fathers worked in professional, managerial, or administrative positions and about 30% had either a clerical or a sales position. The remaining 46% worked as manual workers in production and transport or as operators and laborers. Most of the mothers had ≈10–14 y of schooling and did not work outside the home (95%). On the basis of per capita expenditure, 42% of the families had a high spending capacity (≥250 rupee/mo).

The age-specific mean values for height and BMI of the Calcutta boys, plotted in relation to the 50th percentile of the NCHS reference data, are shown in **Figures 1** and **2**. Also included in Figure 2 are the median curves of the British, Dutch, and French references. Whereas the age-specific mean values for height of the Calcutta boys were ≈2–8 cm below the NCHS median—closely tracking the NCHS reference curve—the mean BMI values of the Calcutta boys were far below the NCHS median. The median curves of the British, Dutch, and French BMI references lay between the Indian and the NCHS samples, although there was still a considerable difference between the 3 European references and the Indian sample.

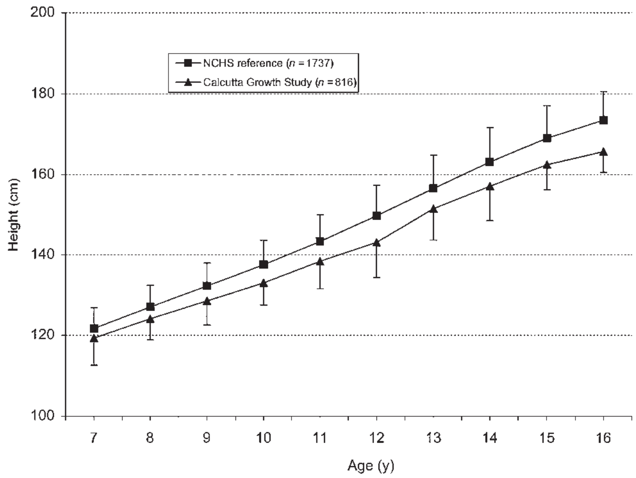

FIGURE 1. Mean (±SD) height-for-age of the Calcutta boys compared with the National Center for Health Statistics (NCHS) reference median.

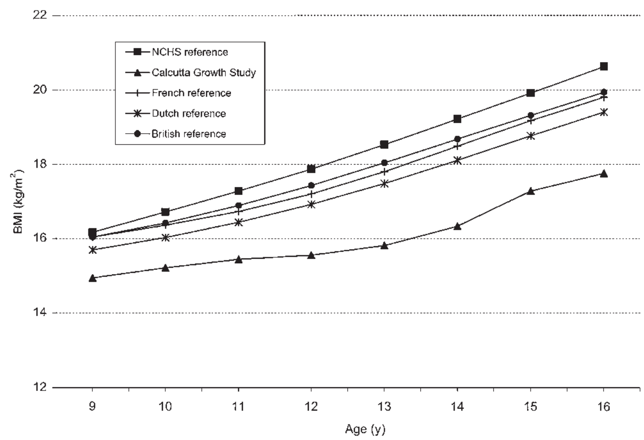

FIGURE 2. Mean BMI-for-age of the Calcutta boys compared with the French, Dutch, British, and National Center for Health Statistics (NCHS) reference medians.

The prevalence of stunting in relation to the 2 cutoffs recommended by the WHO (ie, <3rd percentile and < −2 *z* scores) are shown in **Table 2**. The overall prevalence of stunting was low: 11.2% and 9.4% with use of the 2 cutoffs, respectively. Prevalences across age groups fluctuated from 5.7% to 21.9% below the 3rd percentile and from 4% to 18.8% below −2 *z* scores. This fluctuation was probably to some extent related to the relatively small sample size. As expected, for all age groups, the prevalence below −2 *z* scores was lower than that below the 3rd percentile.

The prevalence of thinness with use of the 5th percentile of the NCHS reference and the −2 *z* score of the French reference data as cutoffs are shown in **Table 3**. The overall prevalence of thinness (50.5%) was 5 times that of stunting. The 5th percentile cutoff yielded a high prevalence of thinness of ≥46% in all age groups with the exception of the 9-y-olds. When we used the French reference and the –2 *z* score cutoff as a basis of comparison, the prevalence of thinness was considerably lower in most age groups, with an overall prevalence of 30.2%. Also presented in Table 3 is the prevalence of being at risk of overweight as defined by the WHO (ie, BMI-for-age ≥85th percentile of the NCHS reference data). The overall prevalence was low (4.7%), with only one subject of the total sample having a BMI ≥ 30.

Presented in **Table 4** and **Figure 3** are the biological parameters of the adolescent growth spurt and the height velocity curve for the Calcutta boys, respectively, as estimated by the Preece-Baines growth model 1. Among the biological parameters, mean age at peak height velocity was 13.0 y and peak height velocity was 7.0 cm/y.

DISCUSSION

Although many studies have been conducted on the anthropometric assessment of nutritional status in preschool children (16), much less such information can be found about older children and adolescents. Among the most important reasons for this lack of information is the difficulty of interpreting anthropometric data in these age groups (1). A WHO Expert Committee (2) recommended using provisionally the NCHS reference and urged that the adequacy of these data for application to populations from different ethnic backgrounds be assessed. The Calcutta Growth Study provided us with an opportunity to evaluate the suitability of applying the NCHS reference data to a middle-class population of apparently healthy adolescent Indian boys.

The results show that with use of the cutoff of −2 *z* scores of the height-for-age NCHS reference, the overall prevalence of stunting in the Calcutta boys was 9%. Although the median height curve of the Indian boys was shaped similarly to that of the NCHS reference, it lay at a mean difference of 5 cm below the NCHS curve (ranging from 2.4 to 7.8 cm). These differences in height were probably the result of a combination of genetic and environmental influences on growth during early childhood.

When we compared the BMI-for-age of the Calcutta sample with the 5th percentile of the NCHS reference data, the prevalence of thinness of the Calcutta sample was 51%. With use of the same classification, similar high prevalences of low BMI-for-age were reported for both stable and displaced populations in developing countries (17–20). In the refugee camp populations there was no evidence of elevated morbidity or mortality. The other surveys

TABLE 2
Prevalence of stunting (low height-for-age)

Age (y)	Height	<3rd percentile[1]	< −2 *z* scores[1]
	cm	%	%
7 (*n* = 63)	119.3 ± 6.7[2]	14.3	12.7
8 (*n* = 87)	124.0 ± 5.3	5.7	5.7
9 (*n* = 96)	128.5 ± 6.0	9.4	7.3
10 (*n* = 75)	133.0 ± 5.5	8.0	6.6
11 (*n* = 97)	138.4 ± 6.9	11.3	10.3
12 (*n* = 96)	143.1 ± 8.8	21.9	18.8
13 (*n* = 98)	151.5 ± 7.9	7.1	7.1
14 (*n* = 93)	157.1 ± 8.6	14.0	10.8
15 (*n* = 75)	162.4 ± 6.2	6.7	4.0
16 (*n* = 36)	165.7 ± 5.2	13.9	11.1
All ages (*n* = 816)	—	11.2	9.4

[1] With use of the National Center for Health Statistics reference population median (2).
[2] $\bar{x}$ ± SD.

TABLE 3
Prevalence of thinness and overweight

Age (y)	BMI	Thinness (BMI-for-age)		Overweight (BMI-for-age)	
		<5th percentile[1]	< −2 *z* scores[2]	≥85th percentile[1]	BMI ≥ 30
	kg/m²	%		%	
9 (*n* = 93)	14.9 ± 2.5[3]	43.0	30.1	7.5	0
10 (*n* = 74)	15.2 ± 2.6	50.0	27.0	10.8	0
11 (*n* = 96)	15.4 ± 3.0	50.0	32.3	7.3	1
12 (*n* = 94)	15.5 ± 2.5	56.4	30.9	5.3	0
13 (*n* = 98)	15.8 ± 1.9	50.0	30.6	0.0	0
14 (*n* = 93)	16.3 ± 2.2	58.1	31.2	1.1	0
15 (*n* = 74)	17.3 ± 2.7	45.9	29.7	2.7	0
16 (*n* = 36)	17.8 ± 3.0	47.2	27.8	2.8	0
All ages (*n* = 658)	—	50.5	30.2	4.7	1

[1] With use of the National Center for Health Statistics reference population median (2).
[2] With use of the French reference population median (8).
[3] $\bar{x}$ ± SD.

chose samples of children who were well enough to attend school survey activities, and 2 of these surveys included adolescents from families with a relatively high socioeconomic status. Yet, the prevalence of thinness was estimated to be >50% (17).

In this study, considering the demographic and socioeconomic characteristics of the sample, the high prevalence of thinness estimated by using the NCHS reference data is unlikely to reflect true levels of acute malnutrition. A possible explanation for these high estimates is the marked skewness of the NCHS age-specific distributions toward higher values compared with other well-nourished populations (2). The uncritical application of this reference may thus provide misleading results and, consequently, lead to inappropriate interventions. Applying the 3 European BMI-for-age reference curves (Figure 2) also yielded unrealistically high prevalences of thinness. For example, applying the French BMI-for-age reference data with the cutoff of −2 *z* scores (Table 3) still gave a prevalence of thinness of 30%.

Comparisons between pooled longitudinal estimates and those from cross-sectional samples indicate that the Preece-Baines growth model can accurately estimate the age at peak height velocity in males when cross-sectional data are used (10–14, 21, 22). With use of this model, the average age at peak height velocity of the Calcutta boys (13.0 y) was younger than that of the NCHS reference (13.5 y) (2) and of other populations in developed countries. A review of growth characteristics from published studies found the age at peak height velocity for European and British samples of boys to be 13.9 y (23). Similarly, surveys in Belgian, British, and US populations showed that the average age at peak height velocity for boys was 14.1, 14.0, and 14.2 y, respectively (10). These results are consistent with those of a review from industrialized countries and well-off populations in developing countries (24). In this review of data from 43 studies, the mean age at peak height velocity for boys of Asiatic origin was shown to be between 0.3 and 0.8 y earlier than that for boys from Indo-Mediterranean, Latin-American, and African populations. Data from 35 studies showed that mean peak height velocities for all 5 ethnic typologies ranged from 7.1 to 7.7 cm/y (24). In the Calcutta sample, peak height velocity was 7.0 cm/y (Table 4). The fact that the Calcutta boys had growth spurt characteristics that matched those of other well-off populations in developing countries strengthens the conclusion that the high prevalence of thinness yielded when applying the NCHS reference is unlikely to reflect true levels of malnutrition in this population.

An understanding of ethnic differences in growth is essential to identifying the extent to which a single reference can be applied worldwide. The similarities in attained growth in preschoolers from developed and affluent developing country populations seem to have settled this controversial issue for the younger age group (1, 2). In adolescent populations, however,

TABLE 4
Biological parameters of the adolescent growth spurt for the Calcutta boys[1]

Parameter	Value
Adult height (cm)	168.2 ± 1.6
Age at take-off (y)	8.8 ± 0.8
Height at take-off (cm)	127.8 ± 3.7
Velocity at take-off (cm/y)	4.4 ± 0.2
Age at peak height velocity (y)	13.0 ± 0.2
Height at peak height velocity (cm)	150.7 ± 1.2
Peak height velocity (cm/y)	7.0 ± 0.4

[1] $\bar{x}$ ± SE; *n* = 816.

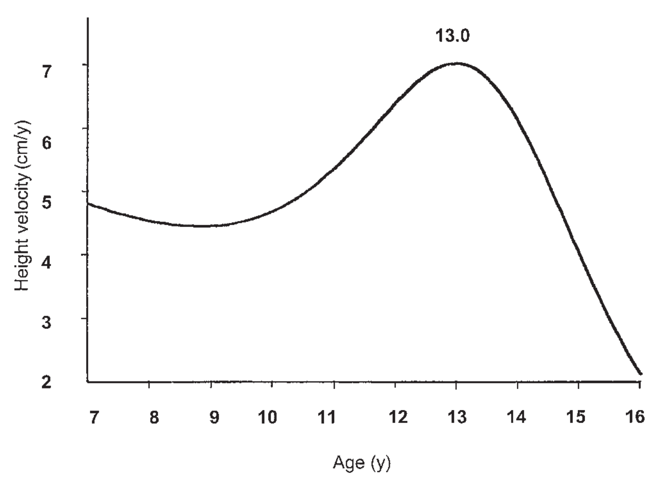

FIGURE 3. Height velocity curve for the Calcutta boys (*n* = 816).

the current evidence is not sufficient to disentangle the contribution of genetic from that of environmental influences on growth. Data on secular trends in both developed and developing countries show a marked intergenerational increase in size and a tendency toward earlier sexual maturation as the socioeconomic conditions and nutritional status of populations improve (24, 25). This secular trend has fundamental implications for the development of anthropometric reference data. As long as such a trend exists, the data will eventually become obsolete. The prescriptive approach taken for the construction of a new international growth reference for young children (26) should also be applicable to older children and adolescents. This would imply developing a reference based on healthy adolescent populations from different ethnic groups in which secular trends in linear growth are likely to have ended and in which there is no evidence of high prevalences of overweight. Such an effort would need to include careful consideration of how to deal with key determinants of growth, such as pubertal development, patterns of physical activity, dietary habits, and growth performance in early childhood. The issues of maturation-related variation and maturation-related misclassification are particularly important. None of the conventional approaches of accommodating maturation-related variation in growth are fully satisfactory (27). The development of noninvasive and valid indicators of maturation that allow maturational status to be meaningfully assessed throughout adolescence are imperative for the understanding and accommodation of maturation-related variation in growth.

There is also a need to streamline the recommended cutoffs for interpreting the different anthropometric indicators in adolescence. Current WHO recommendations advise the use of 2 different cutoffs for assessing stunting or low height-for-age (ie, the 3rd percentile and the -2 z scores) and a third cutoff (ie, the 5th percentile) for assessing thinness or low BMI-for-age. Different cutoffs yield different prevalences and thus it would be necessary to apply the same cutoffs across anthropometric indicators. Since the late 1970s, the WHO has been recommending the z score system because of its several advantages for the classification of malnutrition in preschoolers (2). Thus, it would be logical to also recommend the use of this system for adolescents.

Assessing nutritional status in adolescents continues to be a challenge. To tackle this problem, there is a need for studies of the adolescent growth and maturation characteristics of well-nourished populations from different ethnic backgrounds conducted with use of a common protocol. This vital information may lead to a better understanding of the growth and biological maturation that takes place during puberty. Only with this acquired knowledge can we develop valid guidelines for assessing nutritional status during adolescence. These guidelines will then need to be validated by using functional indicators such as morbidity, work capacity, reproductive outcomes, and mortality.

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