

ORIGINAL COMMUNICATION

Conclusions about differences in linear growth between Bangladeshi boys and girls depend on the growth reference used

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Objective: To examine sex differences in height-for-age z-scores and the percentage stunting among Bangladeshi children estimated using three growth references.

Design, setting and subjects: Data collected between 1990 and 1999 by Helen Keller International's nutritional surveillance system in rural Bangladesh were analyzed for 504 358 children aged 6–59 months. Height-for-age z-scores were estimated using the 1977 NCHS, 2000 CDC and 1990 British growth references.

Results: The shape of the growth curves for Bangladeshi boys and girls, and their positions relative to one another, depend on which of the three growth references is used. At 6 months of age the British reference showed no sex difference whereas the NCHS and CDC showed girls to have higher average z-scores than boys by 0.14 and 0.28 s.d., respectively. While all references showed a faster deterioration of girls' z-scores from 6 to 24 months, the magnitude and direction of the sex differences, and how they changed with age, were different. There was greater disagreement about girls' z-scores than boys. Discontinuities at 24 months in the NCHS and CDC produced jagged curves whereas the British curves were smooth.

Conclusions: The assessment of sex differences in linear growth depends on the growth reference used. Reasons for the different results need to be determined and may aid the final development of the new WHO international growth reference and the guidelines for its use. The findings suggest that anthropometry as a tool to explore the effects of societal gender inequality must be used with caution.

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Introduction

According to studies of children in rural Bangladesh, girls are more likely than boys to die in the first 5 years of life (D'Souza & Chen, 1980; Bairagi, 1986; Koenig & D'Souza, 1986; Fauveau *et al*, 1990). It has been shown, for example, that between the age of 6 and 12 months, the death rate among girls progressively exceeds the death rate among boys

(D'Souza & Chen, 1980) and that the disparity increases with age, so that between 12 and 48 months the female death rate may be almost 60% higher than the male (Koenig & D'Souza, 1986). The female disadvantage in survival has been shown to be a particular problem in South Asia (Coale, 1991).

It has been argued that an unequal treatment of boys and girls may explain the differences in death rates. Studies have shown that when food is allocated within the family a preference is often given to boys (Chen *et al*, 1981; Abdullah & Wheeler, 1985) and that, despite being ill equally as often, girls are less likely to be taken for medical treatment than boys (Chen *et al*, 1981; Bhuiya & Streatfield, 1991; Fauveau *et al*, 1991; Mitra *et al*, 2000).

A study of growth may, like death rates, be a useful way of exploring gender discrimination in a society. A comparison between boys and girls would be based on the assumption that boys and girls who have been equally well fed and well cared for should have the same anthropometric status: anthropometric similarity would imply equality in diet and

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Contributors: A Hye has been the manager of the Nutritional Surveillance Project (NSP) throughout the period of data collection for the present study and was, therefore, responsible for the quality of the data analyzed for this paper. NH was the policy advisor and gender specialist. HM was responsible for the analysis of the data together with NS and MZI. The writing of the paper was done by HM with assistance from SdeP, A Hall and MWB, and with the approval of the other authors.

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health care, while anthropometric difference would imply inequality.

Anthropometric status is typically estimated by comparing a child's height or weight with the median height or weight of a large sample of children of the same age and sex, known as a 'growth reference', and the difference between the observed value of the child and the median of the reference is expressed in standard deviation units, known as 'z-scores' (WHO, 1986; Beaton *et al*, 1990). The most widely used growth reference was published in 1977 by the United States National Center for Health Statistics (NCHS) and is currently recommended by the WHO for use in all countries (Hamill *et al*, 1979). This growth reference has some weaknesses that have been shown to affect the assessment of growth (de Onis & Habicht, 1996; de Onis & Yip, 1996; Victora *et al*, 1998; WHO, 2000) such as the '24-month disjunction' caused by the merging of two data sets at this age and resulting in a sharp increase in average z-scores of a population between 23 and 24 months of age (Dibley *et al*, 1986, 1987; Gorstein *et al*, 1994; WHO, 1995).

Longitudinal studies of child growth in Bangladesh have shown differences between boys and girls. A study tracking the growth of 197 infants in two rural Bangladeshi villages found that, at 6 months of age, 75% of both boys and girls were shorter than the NCHS 10th percentile, a figure which increases to 90% for girls within only 4 months compared with 5–6 months for boys (Brown *et al*, 1982). Girls' linear status deteriorates faster than among boys, so that a sex difference emerges at an age when infants start to require foods in addition to breast-milk and when they are at a greater risk of exposure to infectious diseases (Koenig & D'Souza, 1986).

The usefulness of anthropometric indices for estimating sex differences in growth is difficult to assess since we do not know what the 'true' sex difference is. However, with the availability of alternative growth references to the NCHS, it is now possible to compare their estimates of sex differences in stunting. A recent study of children in the Philippines, for example, used both the 1977 NCHS and 2000 CDC growth references to calculate height-for-age z-scores. It showed that among children aged 6–24 months the NCHS z-scores are lower than the CDC z-scores, and whereas this difference remains constant for boys it increases over time for girls (Eckhardt & Adair, 2002). The British growth reference was published in 1990, and the growth reference of The United States Centers for Disease Control (CDC) was published in 2000. Both references have been developed using a new statistical technique called the LMS method. This method uses the skewness (*L*), median (*M*) and coefficient of variation (*S*) to calculate z-scores (Cole, 1993; Freeman *et al*, 1995; Cole *et al*, 1998; Roberts & Dallal, 2001). The differences in methodology have been shown to affect assessment of growth (Mei *et al*, 1998).

The present study used the NCHS, CDC and British growth references to estimate the severity and prevalence of stunting

in a large sample of Bangladeshi children whose anthropometric measurements have been collected through a long-standing nutritional surveillance system. The main aim of the analysis was to compare the estimates that these references give of sex differences in growth. We also discuss the plausibility of the findings in the light of the existing literature but without further investigation into the reasons for the differences, which may be related to the methods used to construct the growth references.

Subjects and methods

The data analyzed were collected in Bangladesh between 1990 and 1999 by the Nutritional Surveillance Project (NSP) of Helen Keller International (HKI) and the Institute of Public Health Nutrition. The NSP collects data every two months on randomly selected samples of children in rural Bangladesh.

Between the start of the NSP in June 1990 and June 1997, a multistage random cluster sampling design was used to select 500 children from each of the selected 24 sub-districts. Until December 1997, these sub-districts were purposefully selected because they were prone to disasters; thereafter, they were selected to be representative of the six administrative divisions of the country. Access to the Chittagong Hill Tracts was restricted at the time the new sampling procedure was designed and so this area of the country was not included in the national sample. There was one break in data collection between August and December 1997. To estimate a prevalence of wasting of 15% with an absolute precision of 3%, a confidence of 95%, a design effect of 2 to account for the cluster sampling procedure, and allowing for 10% refusals, the sample size was estimated to be 1200 children per round of data collection in each division or 7200 children nationally. To capture seasonal variation in malnutrition and its determinants, cross-sectional data were collected every 2 months in 6 weeks surveys beginning in February, April, June, August, October and December from the same sub-districts (HKI, 1998).

Data were collected in each sub-district by teams of two fieldworkers employed by nongovernment organizations who were sub-contracted by HKI. All fieldworkers had a Bachelor's or Master's degree and previous experience in data collection. HKI gave basic training to all fieldworkers and refresher training before every round of data collection. During the survey, a monitoring team from HKI supervised data collection and checked the equipment used for anthropometric measurements. Quality-control teams, also from HKI, re-visited 5–10% of households without prior notice, within 24 h of the visit by the field teams, to re-collect data and to provide an assessment of its accuracy.

A household was eligible for study if it had at least one child aged 6–59 months, and if the mother was present. If the child was physically disabled or bed-ridden due to illness, the household was excluded. The child's date of birth reported by the mother was recorded. If the mother did

not know the exact date of birth, it was estimated using a Bangla calendar and a list of notable events. The recumbent length of each child aged 6–23 months and the standing height of each child aged 24–59 months were measured using a locally constructed and calibrated length board to a precision of 0.1 cm.

In the analysis the age of each child was calculated by subtracting the date of visit from the date of birth and then truncated to the whole month of age. z-scores of height-for-age were estimated to two decimal places using three growth references: the NCHS reference using Anthro computer software (Sullivan & Gorstein, 1990); the British 1990 growth reference using LMS values in an Excel spreadsheet obtained from the Child Growth Foundation (2 Mayfield Avenue, London W4 1PW, UK); and the CDC growth reference (Ogden *et al*, 2002) using LMS values given on the CDC webpage (Available at National Center for Health Statistics, Centers for Disease Control and Prevention: 2000 CDC Growth Charts: United States. Internet: <http://www.cdc.gov/growthcharts> (accessed 10 February 2002)) using Microsoft Access 2000. Children with z-scores more than 2 s.d. below the median of the reference population were classified as stunted. Children with NCHS z-scores less than -6 or greater than 4 were excluded from the analysis because the validity of the measurement was questioned. It has previously been suggested that six z-scores above or below the NCHS mean can be taken to define extreme values (Sullivan & Gorstein, 1990). However, because Bangladeshi children have a mean height-for-age z-score, compared to NCHS, of around -2 s.d., the upper threshold used to define extreme values in this analysis was taken to be 4 s.d. because the probability of a child to have a z-score higher than this when the mean of its population is -2 s.d. is less than 0.0001 (Altman, 2000).

The mean and standard deviation of z-scores of height-for-age and the percentage of stunted children were calculated for each reference, and separately for each sex and for each month of age. Student's *t*-test was used to compare means. A *P*-value of less than 0.01 was considered to be statistically significant. All statistical analyses were done using SPSS for Windows version 9.0 (SPSS Inc, Chicago, USA).

Results

After excluding 6874 children (1.33%) with extreme z-scores of height-for-age, data were available for 504 358 children: 261 010 (51.8%) boys and 243 348 girls (48.2%). The average sample size for each sex and month of age was 4670 children (range: 4106–5463).

Figure 1 shows the mean z-scores of height-for-age estimated using the three growth references for Bangladeshi boys and girls aged 6–59 months. The '24-disjunction' in the NCHS reference is clearly shown, but there also appears to be one in the CDC. Apart from these obvious anomalies, the three pairs of growth curves show how the nutritional status

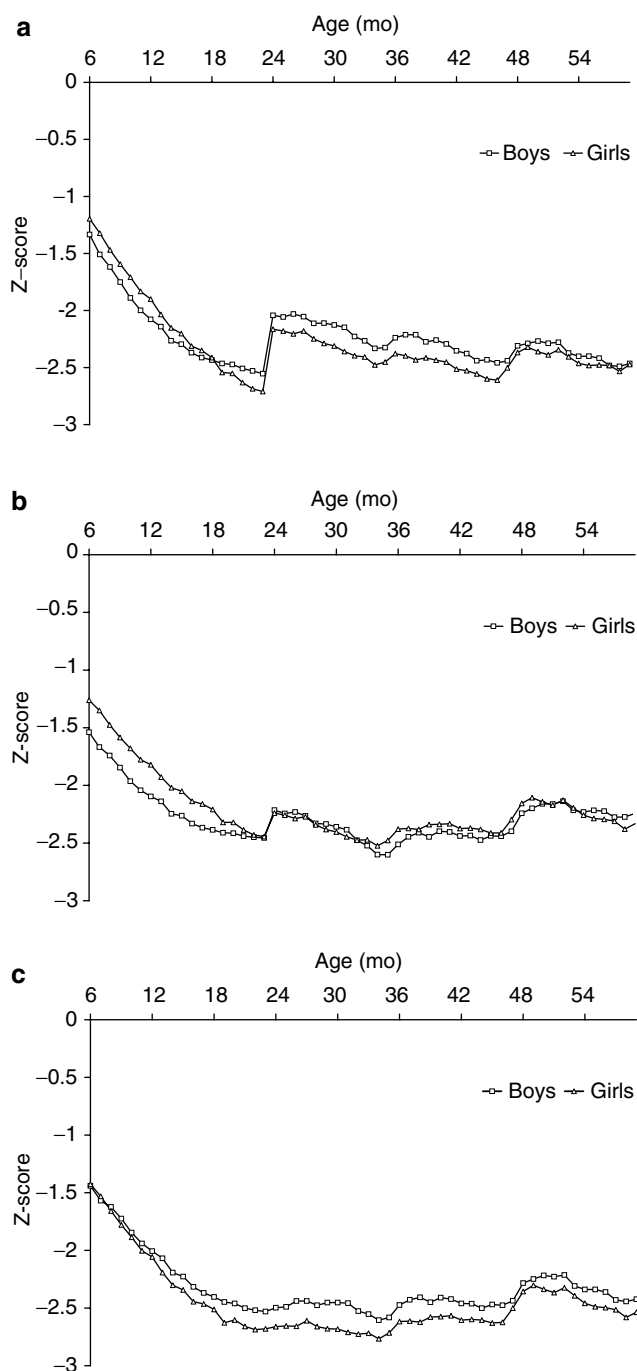


Figure 1 Mean height-for-age z-scores of Bangladeshi boys and girls aged 6–59 months, estimated using the NCHS reference (a), the CDC reference (b) and the British reference (c).

of Bangladeshi children deteriorates between 6 and 24 months of age and remains poor throughout the preschool years, to the extent that more than half were classified as stunted. All the growth references also suggest that girls' height continues to diverge from each reference median

with increasing age, and to diverge for longer than boys: from 18 to 24 months of age, girls' average z-scores were lower by 0.04–0.06 z-scores from one month to the next, whereas boys' average z-score were lower by only 0.01–0.03 z-scores. There is a clear disagreement about the direction and magnitude of sex differences in growth.

Figure 1 suggests that when the growth curves are examined separately for boys and girls, the NCHS, CDC and the British growth curves for girls are similar in shape, as are the boys' curves. On the other hand, when the growth curves of boys are compared with those of girls, three different pictures of relative growth emerge. The NCHS reference indicates that Bangladeshi girls aged 6 months are less stunted than boys by an average of 0.14 z-scores, but that the growth curves gradually converge and cross so that boys are less stunted than girls between 18 and 48 months of age. The CDC reference is similar to the NCHS and shows that girls aged 6 months are less stunted than boys by an average of 0.29 z-scores, and the growth curves gradually converge to meet, so that from around 23 months of age, boys and girls remain stunted to a similar degree. In contrast with the NCHS and CDC references, the British reference shows that girls are generally more stunted than boys over the whole age range covered: although the sexes have similar z-scores at 6 months of age, the curves gradually diverge so that by 23 months of age girls have z-scores that are 0.15 z-scores lower than boys, and girls remain more stunted than boys throughout the preschool years. The result of this disagreement between the references is that it becomes difficult to conclude whether boys are more stunted than girls or girls more than boys.

Figure 2 presents the same growth curves as Figure 1, but shown by sex rather than for each growth reference. The figure shows that for girls below 24 months of age, the NCHS, CDC and British references disagree most in their assessment of growth, as the curves differ in their relative position and are clearly separated. Between 6 and 24 months of age, the range in girls' z-scores at any particular month was 0.30 s.d. on average compared with only 0.14 s.d. for boys ($P < 0.001$).

The impact of the disjunction in the NCHS reference and the apparent disjunction in the CDC reference, both at 24 months of age, is worth examining. Both Figures 1 and 2 show that between 23 and 24 months of age, the height-for-age z-score of Bangladeshi children appears to improve sharply according to the NCHS and CDC references, whereas little change is seen when the British reference is used. The NCHS z-scores increased by more than 0.50 s.d. between 23 and 24 months of age: from -2.55 to -2.04 for boys ($P < 0.001$) and from -2.71 to -2.16 for girls ($P < 0.001$). The CDC z-scores also increased by more than 0.20 s.d., from -2.46 to -2.21 for boys ($P < 0.001$) and from -2.44 to -2.24 for girls ($P < 0.001$). These sharp changes in z-scores are artifacts resulting from discontinuities in both the NCHS and CDC references, as indicated by the unexpected changes in median height of children in the reference population: the

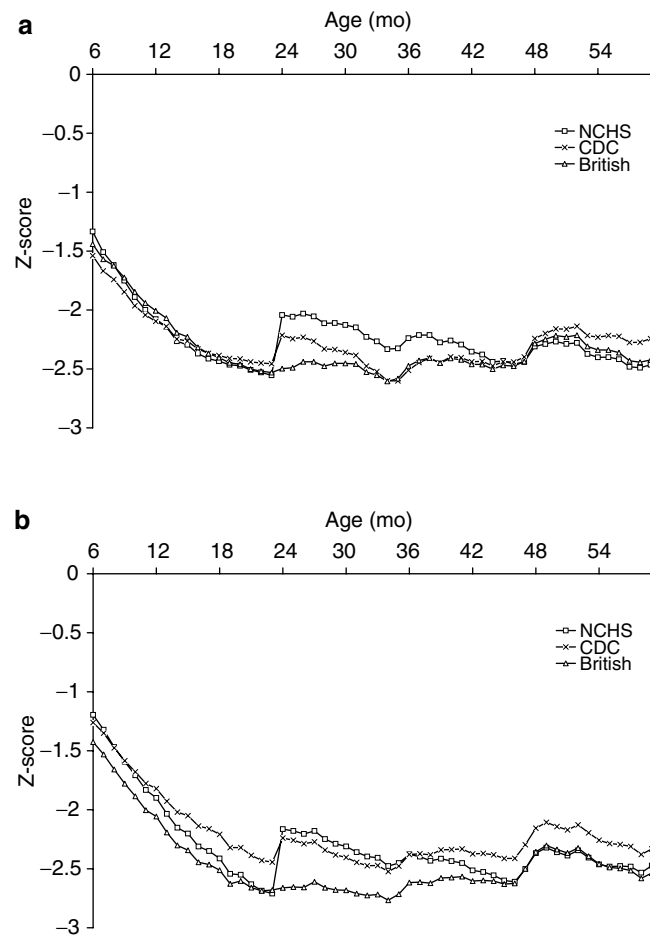


Figure 2 Mean height-for-age z-score of Bangladeshi boys (a) and girls (b) aged 6–59 months, estimated using the NCHS, CDC and British references.

median height of boys and girls in the NCHS reference actually decreases from 23 to 24 months of age by 1.20 and 1.00 cm, it increases only slightly in the CDC by 0.02 and 0.05 cm, whereas in the British, height increases by 0.78 and 0.82 cm. The discontinuities in the NCHS and CDC references between 23 and 24 months have persistent but gradually diminishing effects on z-scores calculated for children up to around 36 months of age. When compared with the British reference, the NCHS reference showed the greatest differences: between 24 and 30 months of age the NCHS z-scores were higher by 0.38 s.d. for boys and 0.35 s.d. for girls.

Figure 3 presents the difference in height-for-age z-score when the average z-score for girls per month of age is subtracted from the average z-score for boys. The distance from the curve to the x-axis represents the size of the sex difference in linear growth. The figure shows that girls' linear status deteriorates faster than boys' during the first 2 y of life, regardless of which growth reference is used in the analysis,

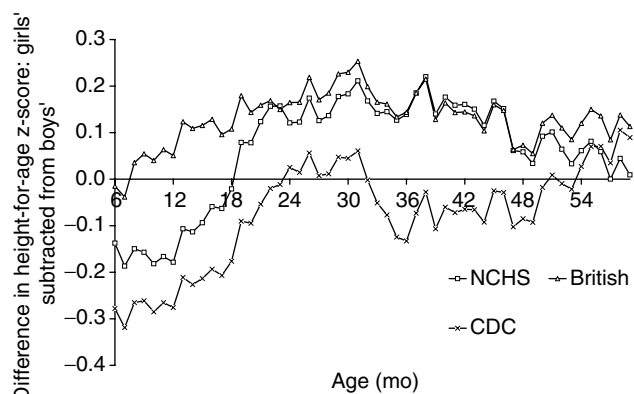


Figure 3 The difference in height-for-age z-score between boys and girls, estimated using the NCHS, CDC and British growth references, when girls' average z-score is subtracted from boys' at each month of age.

and that the gap between the sexes remains constant or narrows slightly thereafter. The growth references do not agree, however, on the size of the sex difference at 6 months of age. Whereas the British reference detects no difference in average z-score (0.01 s.d., $P=0.554$), the NCHS and CDC estimate girls to have z-scores 0.14 and 0.28 s.d., respectively, higher than boys ($P<0.001$).

Figure 4 shows the percentage of Bangladeshi boys and girls by month of age who were classified as stunted calculated using all three growth references. The figure illustrates the disagreement in estimates of stunting within this large sample of malnourished Bangladeshi children. The differences between the growth references are clear at the age of 6 months, both in absolute and relative degrees of stunting. The NCHS estimates 24% of boys and 20% of girls to be stunted, the CDC estimates 32 and 22% to be stunted and the British reference estimates 29 and 32% to be stunted.

Figure 4 also shows the impact on estimates of stunting of the discontinuities at 24 months in the NCHS and CDC reference. The figure reveals that between 23 and 24 months of age, there is a drop in the percentage of children who were stunted in comparison with the NCHS reference from 69.2 to 52.4% (16.8%) for boys and from 74.5 to 56.0% (18.5%) for girls. With the CDC reference, the percentage fell from 65.7 to 57.9% (7.8%) for boys and from 66.5 to 59.0% (7.5%) for girls. In contrast, the British reference showed a negligible change in the prevalence of stunting around 24 months of age for Bangladeshi children (<1%). The effects of the discontinuities in the NCHS and CDC references at 24 months persist for at least 12 months, if not longer, so the percentage of children classified as stunted was lower than might otherwise have been expected. NCHS estimates of stunting are generally lower than those of the CDC or British reference. Particularly large differences in estimates of stunting between the three growth references were found between 24 and 36 months of age: the NCHS, CDC and

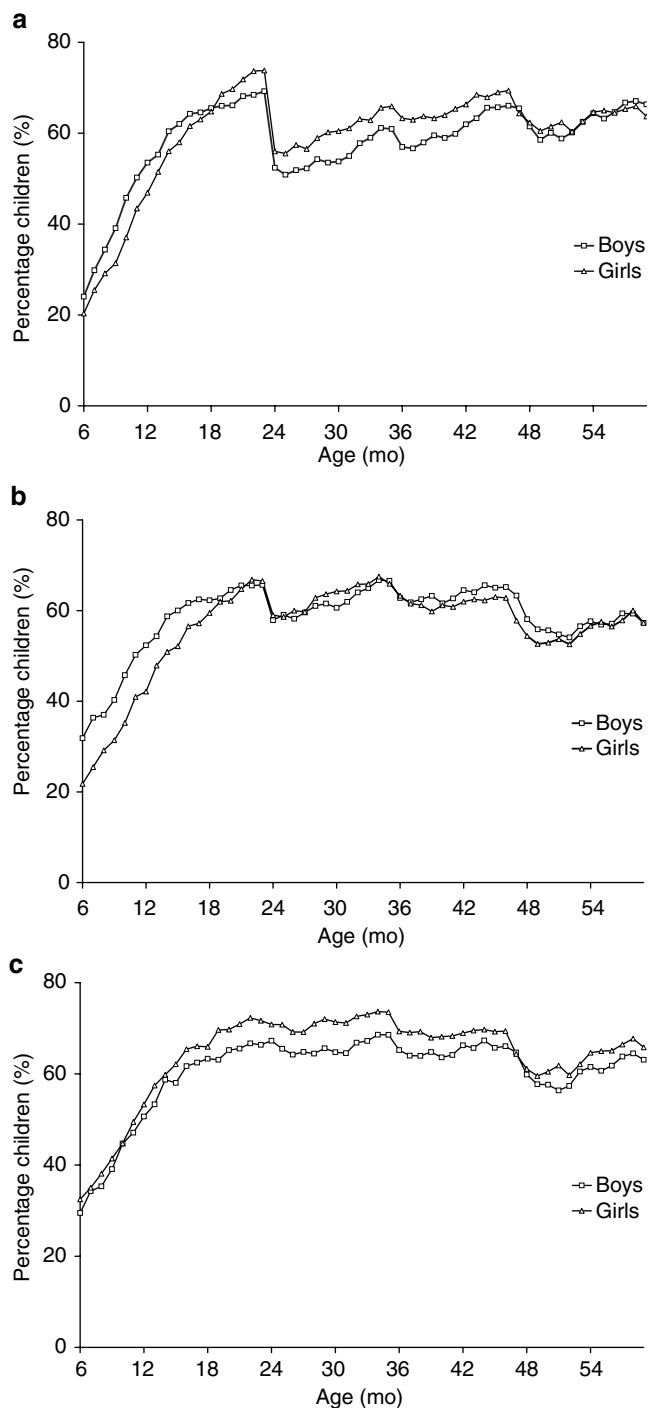


Figure 4 Percentage stunting (height-for-age z-score <-2 s.d.) among Bangladeshi boys (a) and girls (b) aged 6–59 months, estimated using the NCHS, CDC and British growth references.

British references estimated that 57.7, 62.4 and 68.7% of all Bangladeshi children, respectively, were stunted. Large differences were also found at 6 months of age with 22.2, 26.9 and 31.0% of all children estimated to be stunted.

Discussion

The shape of the growth curves for Bangladeshi boys and girls, and their positions relative to one another, depend on which of the three growth references is used to assess their height. For example, for girls less than 24 months old the three growth curves were similar in shape, but the z-scores differed in absolute magnitude: they all showed that girls' height continued to diverge from the reference median with increasing age, and to diverge for longer than boys, but they disagreed on the severity of stunting among girls. The result of this disagreement is that it is difficult to conclude whether girls were more stunted than boys or *vice versa*, and to examine these differences by age.

A feature, and perhaps an inherent danger, of using anthropometry to explore sex differences in nutrition is that the relative position of boys' and girls' growth curves is prone to being markedly altered by a comparatively small shift in one of the reference curves. An example of this is presented here for children less than 24 months old: although the three growth references gave similar estimates of stunting among Bangladeshi boys, they disagreed more in their estimates for girls. The girls' growth curve therefore shifts according to the reference used, resulting in three very different pictures of the relative growth of boys and girls.

The figures clearly illustrate the problem of the '24-month disjunction', due to the merging of two data sets at this age to create the NCHS growth reference. The effect of the disjunction is a sharp increase in average z-scores between 23 and 24 months of age. The CDC also displays discontinuities at this age, for reasons that are not clear. In contrast, the British reference provided growth curves that were relatively smooth for both Bangladeshi boys and girls, and suggested three things about the growth of Bangladeshi children. First, that boys and girls were stunted to the same degree at 6 months of age; second that girls became progressively more stunted than boys thereafter; and third, that girls remained more stunted than boys throughout the preschool years. It is plausible that any impact of inequalities in diet and health on growth would take some time to show, so that girls' and boys' nutritional status would be similar at about 6 months, and then gradually diverge with age. This was the picture of growth given by the British growth reference, and it is consistent with what is known about the health and nutrition of children in rural Bangladesh. Small-scale longitudinal studies of infants have previously shown that sex differences in nutritional status or death rates progressively emerge during the second half of the first year of life (Brown *et al*, 1982; Koenig & D'Souza, 1986; Fauveau *et al*, 1990, 1991).

The findings suggest that anthropometry as a tool to explore the nutritional effects of societal gender inequality needs to be used with caution. In Bangladesh nutritional inequality appears to exist between boys and girls, but any conclusions about the magnitude and direction of these differences — which seem to change with age — are largely dependent on the growth reference used to provide the

benchmark by which children are compared. Further research is needed to explore the reasons behind the discrepancies that may aid the final development of the new WHO international growth reference and the guidelines for its use (Garza & de Onis, 1999).

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