Growth Reference Charts and the Nutritional Status of Indian Children

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Abstract

We evaluate the growth performance of Indian children of age 0 to 3 using data from the 1998-99 National Family and Health Survey, making use of the new child growth standards developed by the World Health Organization' Multicentre Growth Reference Study. We find that the new charts lead to an increase of 4.2 million in the estimated number of stunted children, and an increase of 2.3 million in the estimated number of wasted children. The estimated number of underweight children *decreases* instead by 2.1 million. We also use data on ethnic Indians living in the United Kingdom to provide evidence on the height genetic potential of Indians. We find that children of Indian ethnicity who live in the UK have anthropometric outcomes comparable to those in commonly used growth standards and that the height of ethnic South Asian in the sample is negatively related with the amount of time spent outside the United Kingdom.

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1 Introduction

Child nutritional status is an essential component of a country's overall human development. There is a growing consensus that poor nutritional status during childhood (and in utero) can have long-lasting scarring consequences into adulthood, both in terms of health and mortality, and in terms of other measures of human capital such as schooling and productivity (Maluccio et al. 2005, Behrman et al. 2006, Glewwe and Miguel 2007). In the last three decades, countless studies have measured child nutritional status in developing countries using as reference growth charts introduced in 1977, estimated from a population of U.S. children by the Center for Disease Control and prevention and the National Center for Health Statistics. The use of such standards had been recommended by the World Health Organization (WHO) for international use since the late 1970s, based on studies suggesting that the growth patterns of healthy children are similar across different ethnic groups (Habicht et al. 1974, Waterlow et al. 1977, WHO Working Group 1986, Dibley et al. 1987a, Dibley et al. 1987b, Martorell and Habicht 1986, Gorstein et al. 1994). Agarwal et al. 1991 and Bhandari et al. 2002 specifically evaluate the adequacy of the U.S. charts for India, and find that the growth performance of Indian children of age five and below living in affluent families is broadly comparable to that of U.S. children, although not in all the regions analyzed.[1]

Estimates of the extent of child malnutrition in India invariably describe a population whose growth performance is very poor (Svedberg 2000, Borooah 2003, Pande 2003, Borooah 2005, Nandy et al. 2005, Svedberg 2006, Tarozzi and Mahajan 2007). Given that this country account for approximately one sixth of the world population, the extent of malnutrition in India is clearly important for anyone concerned with the worldwide magnitude of the problem.

In 1997, the WHO initiated the Multicentre Growth Reference Study (MGRS), with the purpose of constructing new standards for normal early childhood growth under ideal environmental conditions. The charts would be used to assess the nutritional status of children under five years of age regardless of ethnicity, socioeconomic status and feeding practice. The new charts resulting from this effort have been estimated with data from 8440 healthy breastfed infants and young children from Brazil, Ghana, India, Norway, Oman and the United States (World Health Organization

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[1] Agarwal et al. 1991 study growth data from 1429 boys and 1206 girls aged 0-72 months from affluent sections of Bangalore, Calcutta, Delhi, Ludhiana and Varanasi. They find that child weight and height in Delhi and especially Ludhiana nearly corresponded to those in the international growth standards, while remaining at lower levels in the other three cities. Bhandari et al. 2002 use a sample of 341 children aged 12-23 months born from affluent parents in south Delhi. They find mean z-scores for weight-for-age, length-for-age and weight-for-length equal to -0.45, -0.28 and -0.32 respectively.

2006).[2] New charts have also recently been introduced for the United States, to overcome some concerns with the previous references (Kuczmarski et al. 2000). Throughout the paper, we refer to the three different sets of reference charts as follows: CDC-WHO77 will indicate the US-based charts whose use was recommended until recently by the World Health Organization; WHO-2006 will denote the revised WHO charts and CDC-2000 will indicate the revised US charts.

The first purpose of this paper is to use data from the 1998-99 National Family and Health Survey, together with the revised WHO-2006 growth charts, to re-evaluate the height and weight of Indian children under 3 years of age.[3] We find that, relative to estimates obtained using CDC-WHO77 references, the new charts lead to an increase of 4.2 million in the estimated number of stunted children (from 42 to 48%), and an increase of 2.3 million in the estimated number of wasted children (from 15 to 18%). The largest increase occurs for the proportion of stunted boys. The estimated number of underweight children decreases instead by 2.1 million (from 44 to 41%), almost exclusively through the impact of the new charts on the extent of girl underweight.

Our second purpose is to contribute further evidence on the adequacy of international growth charts for the Indian population by using data from individuals of Indian ethnicity living in the United Kingdom. With similar purposes, other studies have used information on the nutritional status of children of different ethnicity living in rich countries. Duggan and Harbottle (1996) find anthropometric measurements comparable to those of the CDC-WHO77 references for a sample of 169 healthy children aged between 4 and 40 months of Pakistani and Bangladeshi origin living in Sheffield (UK). Yip et al. (1992) and Mei et al. (1998) study the growth patterns of children of Asian refugees in the United States, and conclude that factors such as diet and health services, rather than genetic factors, explain most of the inter-country variation in child anthropometric indices. Nguyen et al. (2004) show that growth patterns of Vietnamese infants who reside in Australia are close to the U.S. reference charts, despite their parents' anthropometric indices being below reference. Gjerdingen et al. (1996) find, instead, that a sample of 0 to 5-year old children of Hmong ethnicity living in the United States were slightly heavier then the CDC-WHO77 reference mean for the first months after birth, and shorter thereafter. Smith et al. (2003) show that Maya-American children are taller, on average, than their counterparts in Guatemala, but are also more likely to be overweight.

Using data from the 1999-2000 Health Survey for England, we find that children of Indian

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[2] The new charts can be found together with the corresponding documentation at `http://www.who.int/childgrowth/standards/en/ap.`

[3] The choice of the age threshold is imposed by data constraints, see Section 2.

ethnicity living in the United Kingdom have anthropometric outcomes very close to those in the WHO-2006 standards. We also find that, even after controlling for income per head, height of ethnic Indians in the sample is negatively associated with the amount of time spent outside the UK. Overall, these findings are consistent with the argument that socio-economic and epidemiological factors, and not genetic differences, are the major causes of the relatively poor growth performance of the Indian population. At the same time, these results should be interpreted with caution, because ethnic Indians who move to the UK may not be representative of the same genetic pool as that of other Indians who do not migrate.

2 Data

To evaluate the nutritional status of Indian children, we use data from the second round of the National Family and Health Survey (NFHS), completed in India between November 1998 and December 1999.[4] The NFHS is one of the Demographic and Health Surveys carried out in many developing countries—adopting a largely standardized questionnaire—with the primary goal of collecting information on health, fertility and other family issues from ever married women of fertility age. The survey contains reports from approximately 90,000 women of age 15-49, and is constructed to be a representative sample for the whole of India, both rural and urban. Table 1 reports selected summary statistics. Anthropometric measurements, including height and weight, were taken for children up to three years of age. The number of women with at least one child under the age of 3 (U3) in the sample is 20,493 for rural and 7,293 for urban areas. Schooling is overall very low, especially in rural areas, where two-thirds of women are illiterate. Only about one fifth of women are either employed or self-employed. Selected indicators also indicate poor health. The hemoglobin level is below 12 grams per deciliter of blood in more than half of the sample. This threshold is sometimes used to indicate iron deficiency (Thomas et al. 2006). The body mass index (BMI) is below 18.5 for 43% of women in rural areas and 31% in urban areas.[5]

The second source of data is the 1999-2000 round of the Health Survey for England (HSE). This survey is carried out by the Joint Health Surveys Unit of the National Centre for Social Research and the Department of Epidemiology and Public Health at University College, London.

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[4] The data and the documentation can be accessed at `http://www.nfhsindia.org/index.html`.

[5] BMI is calculated as weight in kilograms divided by the squared of height measured in centimeters. Values of BMI below 18.5 have been often associated with higher mortality for men, while for women even higher thresholds have been often used (Waaler 1984, Payne 1992)

The 1999-2000 round was specifically formulated to also allow the analysis of health among minority ethnic groups.[6] A General Population Sample was selected drawing about 6,500 addresses from the Postcode Address File in 312 postal sectors. In each sampled household, information were collected on all adults and children, unless the household included more than two children, in which case only two selected at random were surveyed. A special (Ethnic Boost) sample of about 26,500 addresses was then selected within another 340 postal sectors with the specific scope of collecting detailed health information for households belonging to the most populous six minority ethnic groups: Black Caribbean, Indian, Pakistani, Bangladeshi, Chinese and Irish. About 37,600 addresses adjacent to those sampled as described above were also covered by focused enumeration. Interviews were attempted only with respondents from the specified minority ethnic groups. Among eligible informants at an address, a maximum of four adults and three children were selected for interview, at random if necessary. For each individual included in the survey, HSE also reports weight, height, age, ethnicity, household income, and country of birth. Unfortunately, weight and height were not collected for children below two years of age, so that comparisons of child growth outcomes between NFHS and HSE data is only possible for children of age two to three.

2.1 Measures of Child Nutritional Status: Old and New Growth Charts

The three most widely used indicators of child nutritional status are weight-for-age, height-for-age, and weight-for-height. Height-for-age is the preferred measure of long-term nutritional status. Because weight can change in a relatively short period of time as a consequence of changes in nutritional intake and/or health status, weight-for-age and weight-for-height are better measures of short term nutritional status. However, the former index does not distinguish between small but well fed children and tall but thin ones, so that weight-for-height is usually the preferred indicator for current nutritional status. One more advantage of weight-for-height is that—unlike the other two indicators—it does not require exact knowledge of age in months, because the reference group is a population of children of the same gender and height, irrespective of age (Gorstein et al. 1994). This factor can pose a significant advantage in surveys such as the NFHS, where weight and height are measured by well trained technicians, but age recording (in months) must usually rely on the mother's report. In populations where illiteracy is very common, child age is often reported with error. In Figure 1, we show the distribution of reported child age in months in the NFHS, separately

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[6] For detailed information on the data set, see Erens et al. 2000. The data are available at `http://www.data-archive.ac.uk/findingData/hseTitles.asp`.

for different levels of mother's schooling.[7] The distribution of reported child age presents a clear pattern, although it becomes somewhat less visible when mother's education increases. Note, however, that even among illiterate mothers there is no evidence of reports clustering at "focal ages" such as 0, 6, 12, or 18 months.

Let g denote the reference group a child is being compared to, and let x_{ig} denote height or weight for child i compared to a reference g. The most common approach to evaluate growth performance transforms the anthropometric indices into a *z-score*, calculated as $(x_{ig} - \bar{x}_g)/s_g$, where $\bar{x}_g$ and s_g are respectively the mean (or median) and the standard deviation of the indicator for children within the same group in the benchmark population. In the CDC-WHO77 charts, the skewness in the distribution of the anthropometric indicators in the reference population was taken into account by using different standard deviations s_g, depending on whether x_{ig} remained above or below $\bar{x}_g$. When the corresponding nutritional indicator in the reference population is approximately normally distributed, z-scores are very easy to interpret. For instance, if a boy's weight-for-height z-score lies below -1.645 then his weight is below that of 95% of boys in the reference population with the same height. A child is usually identified as *stunted* if height-for-age z-score is below -2, and as *underweight* or *wasted* if the z-score for respectively weight-for-age or weight-for-height is below the same threshold.

For several years, the CDC-WHO77 charts have represented the most widely used reference to assess child nutritional status. These standards have been introduced in 1977, after being developed in the United States by the National Center for Health Statistics (NCHS) and the Center for Disease Control and prevention (CDC). Their use has became especially common after the WHO recommended their use for the evaluation of child growth worldwide (Waterlow et al. 1977, World Health Organization 1978, Dibley et al. 1987a). The CDC-WHO77 charts have also been adopted for the calculation of the z-scores included in the NFHS data used in this paper. The use of these charts, however, has never been unanimously accepted (especially for children aged 0-24 months) neither for use within the U.S., nor as an international standard. Detractors have called attention to several limitations, perhaps more importantly the sample used for their construction. Such sample only included Caucasian infants from predominantly middle-class families (and, for younger children, coming from a single community). Other shortcomings were the long time interval between successive measurements of the children in the sample, and the fact that a large number of measured infants were bottle-fed (Kuczmarski et al. 2000).

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[7] In this survey, child age in month is calculated as the difference between interview date and day of birth. Birth dates were reported by the mother, and the child month of birth was further probed asking "what is his/her birthday".

The same shortcomings that led to a revision of the charts for use within the U.S. also contributed to argue for a revision of the charts used for international comparisons. Of particular concern was the fact the growth of infants fed according to practices recommended by the WHO appeared to remain *below* the standards set in the CDC-WHO77 standards, especially after 4-6 months of age (World Health Organization Working Group on Infant Growth 1995). While the charts were constructed with a sample of bottle-fed infants, a practice which appears to maximize growth within the first year of life, exclusive breast-feeding is recommended by the WHO in the first 4-6 months of life, with a mix of breast-feeding and supplements recommended afterwards and up to at least two years of age. These recommendations appear to be especially important in developing countries, because several studies document a negative association between breast-feeding and infections (Hanson et al. 1994, López-Alarcón et al. 1997, Mårild et al. 2004 and references therein). As a result of the combined shortcomings of the CDC-WHO77 charts, the WHO initiated the Multicentre Growth Reference Study (MGRS), which between 1997 and 2003 produced a new set of references for international comparisons that has become recently available.[8] The new charts are based on healthy children from Brazil, Ghana, India, Norway, Oman and United States, living under conditions likely to allow the full achievement of their genetic growth potential, whose mothers did not smoke and followed the WHO recommended feeding practices.[9]

Unlike the old references, the new charts have been developed using an LMS model (Cole 1988, Cole and Green 1992), which takes explicitly into account the skewness and non-normality of the distribution of weight and height in the reference population.[10] In this approach, the z-score for a given anthropometric measure x_{ig} is calculated using mean and standard deviation not of the same measures in the reference group, but of a Box-Cox transformation of the measures.[11] In this way, the z-score for child i compared to a reference group g is calculated as:

$$z_{ig} = \frac{(x_{ig}/M_g)^{L_g} - 1}{L_g S_g}, \tag{1}$$

where L_g is the "power" of the Box-Cox transformation and M_g and S_g are the mean and the standard deviation of the transformed variable in the reference population. Hence, the new charts provide the parameters L_g, M_g and S_g necessary for the calculation of the expression in (1). Such

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[8] For comprehensive technical descriptions of the new charts, as well as for details on the rationale of their development, see World Health Organization 2006, which also compares the revised charts to the CDC-WHO77 references and the new CDC-2000 charts, which have replaced the previous reference within the United States.

[9] It should be noted that even the new charts have not been unanimously accepted (see, for instance, Klasen and Moradi 2000).

[10] The same approach is used in the revised CDC-2000 references for the U.S. (Kuczmarski et al. 2000).

[11] See Box and Cox 1964, or Davidson and MacKinnon 1993, Ch. 14.

parameters are gender-age specific for the construction of height-for-age and weight-for-age z-scores, while they are gender-height specific for weight-for-height.

3 Child Nutritional Status in India with New and Old Growth Charts

We now move to the evaluation of the anthropometric performance of U3s in India using the alternative reference charts described in the previous section. Figures 2 to 4 show densities of z-scores for height-for-age, weight-for-height and weight-for-age, by gender and rural or urban residence. All densities are estimated nonparametrically using standard kernel estimators, choosing the bandwidth according to the robust criterion described in Silverman (1986) for approximately normal distributions, and using a biweight kernel. In each graph, we plot two densities. The continuous lines display the densities of z-scores calculated using the new WHO-2006 charts. The dashed lines represent the estimated densities of the z-scores included in the NFHS dataset (which use the CDC-WHO77 standards). In all cases, the WHO-2006 curves appear to have more mass on very low values than the CDC-WHO77 curves. At least in part, this is due to the truncation criterion used in the NFHS, where weight-for-height z-scores are truncated below -4 or above 6, while weight-for-age and height-for-age z-scores are truncated for absolute values above 6.[12] While for height-for-age and weight-for-height the CDC-WHO77 lines remain below the WHO-2006 curves over most of the range until very near the -2 threshold, the weight-for-age densities cross around -4. As a consequence, it appears that the use of the new charts *increases* the estimated extent of stunting and wasting among Indian U3s, while it *decreases* the extent of underweight.

In Table 2, we report estimates of the fraction of stunted, wasted and underweight children using the same data, by gender and sector. We also report an estimate of the total number of Indian children in each gender-sector combination.[13] To enhance the comparability between estimates obtained using different references, we also report results obtained with WHO-2006 charts but using the same truncation criterion used in NFHS.

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[12] Figures which also include densities estimated using new reference charts with the same truncation rule as NFHS are available upon request from the author.

[13] These totals are calculated assuming a total Indian population at the end of the 1990s of one billion, and estimating the fraction in each specific demographic group using the data in NFHS. We estimate that 73.6% of Indians lived in rural areas and that the fraction of females in the population was .486 in urban areas, and .493 in rural areas. In urban India, children below three years of age accounted for 5.9% of the male population, and 5.8% of the female population. In rural areas, the two proportions were 7.4 and 7.1 percent respectively.

In most cases, the choice of standards affects the results considerably. For instance, when height-for-age z-scores are calculated using the new reference values, the fraction of stunted boys in urban areas increases by 10 percentage points, from 34 to 44%. Clearly, the truncation criteria adopted by the NFHS for the calculation of the z-scores only explain part of the difference with respect to the figures calculated using the new WHO-2006 charts. If we use the same truncation criterion used by the NFHS together with the WHO-2006 references, we estimate an increase in stunting for urban boys by 8 percentage points, from 34 to 42%. This corresponds to an increase of 644,000 (= 8.05 million $\times 0.08$) in the estimated number of stunted boys. The fraction of stunted girls increases by 4 percentage points, from 37 to 41%, which corresponds to 300,000 girls (7.5 million $\times 0.04$). In rural areas, where poverty and malnutrition are more widespread than in cities, the use of the new charts increases estimated stunting from .47 to .55 among boys (that is, an increase of $27.7 \times 0.08 = 2.216$ million children), and from .50 to .54 among girls (that is, by about $25.9 \times 0.04 = 1.036$ million children). Overall, the new charts lead approximately to a 4.2 million increase in the number of stunted children in India in 1998-1999.

To a lesser extent, the new charts also increase the estimated magnitude of wasting, which for both genders and in both sectors characterizes a much smaller fraction of children than stunting. This is a common finding in developing countries, where children's low weight is usually partly "balanced" by low height. Overall, the figures in Table 2 show that the (truncated) z-scores calculated using the WHO-2006 charts lead to an increase of 2.3 million in the number of wasted children.[14]

As suggested by a visual inspection of the densities in Figure 4, the effect on underweight is opposite, although the change is concentrated on girls, and the effect on severe underweight is very limited. The fraction of underweight boys decreases from 37 to 36% in urban areas, and from 48 to 47% in rural areas. However, among girls the decline is from 40 to 34% in urban India and from 52 to 47% in rural areas. Overall, these figures imply a 2.1 million decline in underweight among Indian children aged 0-35 months.[15]

It is also worth noting what these comparisons imply for gender differences in z-scores. The existence of preference for sons over daughters is a well-documented reality in India, particularly in the North-West. Gender inequality has been documented for different outcomes, among which are sex-selective abortion, schooling, health and health care, and child mortality (Basu 1992, Dasgupta 1993, Murthi et al. 1996 and Drèze and Sen 2002). Some studies have found bias against girls in

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[14] This figure is calculated as $8.05 \times 0.02 + 7.5 \times 0.03 + 27.7 \times 0.04 + 25.9 \times 0.03$.

[15] This figure is calculated as $8.05 \times 0.01 + 7.5 \times 0.06 + 27.7 \times 0.01 + 25.9 \times 0.05$.

nutrient intakes and nutritional status (Behrman 1988a, Behrman 1988b). However, the evidence about gender bias in nutritional status remains inconclusive, as discussed in Harriss (1995). More recent evidence is provided in Tarozzi and Mahajan (2007), who use the same NFHS data used in this paper together with the previous round, completed in 1992-93. They find that in 1992-93 the distribution of z-scores for height-for-age and weight-for-age did not point to systematically worse performances among girls. However, they also find a movement towards boy advantage in rural areas in North India.

The figures in Table 2 suggest that the choice of reference leads, in some cases, to a reversal of the gender differences in nutritional status. Specifically, the new charts eliminate the boy advantage in stunting and underweight. In both rural and urban areas, the difference between boy and girl stunting changes from −3% with CDC-WHO77 charts to +1% with the new standards. The boy versus girl difference in underweight switches from −3% in urban areas to +2%. In rural areas the shift is from −4% to zero. The extent of wasting remains instead essentially unchanged. These findings point to the importance of using the same set of reference charts when making statements about differences in gender bias in anthropometric outcomes across different countries or between different periods within the same area.

Estimates of the fraction of z-scores below −2 or below −3 in India, as calculated using the CDC-WHO77 and the WHO-2006 charts, are also reported in the WHO Global Database on Child Growth and Malnutrition (World Health Organization 2008). This database is periodically updated as new data become available, and includes summary measures of child anthropometric indices for India as well as for most other countries in the world (de Onis and Blössner 2003). For some data sets prior to 2006, results obtained with both growth charts are reported. The 1998-99 Indian NFHS is one of these data sets and the tabulations report separate estimates of the extent of stunting, wasting and underweight for different gender and age groups or by sector.[16] However, a direct comparison of these figures between the two references is not offered. Also, the results are not disaggregated by gender *and* sector, so that a direct comparison with the figures in Table 2 is not possible. Overall, these tabulations show that using the CDC-WHO77 charts 43.6% of up to 3-year old boys were stunted, 15.9% were wasted, and 45% were underweight. Among girls in the same age range, 48.5 were stunted, 15.4% were wasted, and 46.4% were underweight.[17] Using instead WHO-2006 charts, 51.2% of boys are stunted, 20.5% are wasted and 45% are underweight. Among

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[16] The tabulations and references to the data sets they refer to can be found at `http://www.who.int/nutgrowthdb/database/countries/ind/en/`.

[17] See `http://www.who.int/nutgrowthdb/database/countries/nchs_reference/ind.pdf`, p. 21.

girls, 50.9% are stunted, 19.2% are wasted and 43.8% are underweight. These results can be seen as an aggregation of the sector-gender specific estimates described in the previous paragraphs, and so they confirm their major implications. First, the new charts substantially increase the estimated prevalence of stunting and wasting, and they decrease the fraction of underweight girls while leaving unchanged the fraction among boys. Second, the WHO-2006 charts switch the sign of the gender differential in stunting and underweight, so that the relative performance of girls along these two dimensions becomes better than for boys.

3.1 Anthropometric Performance of Indian Children from Better-off Families

Overall, regardless of gender, sector, anthropometric index or reference charts, most Indian children appear to have relatively poor growth performances. Poor growth is not limited to children who live in very poor households. Table 3 shows the proportion of stunted, wasted and underweight children, by gender, as a function of a "Standard of Living Index" (SLI). All statistics are calculated using the WHO-2006 charts. The NFHS does not include data on income or consumption, but it records information on ownership of a large number of physical assets and other wealth indicators. The Standard of Living Index, which is included in the database, is constructed by summing up scores assigned to each indicator, and then categorizing each household as having either a "low", a "medium" or a "high" index.[18] Not surprisingly, there is a monotone relationship between the SLI and growth performance. However, the figures in the last row of Table 3 show that even in households with a high index, approximately one third of children are stunted, 15% are wasted and one quarter are underweight. Note also that the gender bias *in favor* of girls is maintained for all standard of living categories.

The SLI, being based only on measures of asset ownership, is certainly a rough measure of living standards, and there is considerable heterogeneity among households with a high SLI. For instance, some of these households are composed of illiterate individuals, while others live in slum areas, or have no access to sanitation. Therefore, these findings are not necessarily at odds with those in Agarwal et al. 1991 and Bhandari et al. 2002, who find that the growth performance of Indian children born from "elite" families are comparable to those of the US population. We explore this issue further using only information from families where malnutrition should be unlikely. Out of the approximately 5100 children living in families with a high SLI, we select those from urban areas, where both parents have at least a high school diploma, live in a house with a flush toilet

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[18] See the NFHS final reports (p. 41), available at `http://www.nfhsindia.org/india.html`, for details on the calculation of the score.

with a separate room used as kitchen and whose family owns car, color television, telephone, and refrigerator. This selection procedure reduces the sample to only 212 children with valid height and weight records. The results in Table 4 show that the mean and median of weight-for-height z-scores are close to zero, suggesting marked similarity with the reference. However, height performances remain, on average, lagging behind those of the children in the reference. The mean z-score for height-for-age is $-.877$, which corresponds to the 20th percentile of the reference distribution. Also, 20% of these children are stunted, and 9 percent are severely stunted, that is, their height z-score is not larger than -3. Weight-for-age performances are worse, but not too far, from those for weight given height.

Overall, relative to the new growth standards developed by the WHO, Indian children from relatively well off families appear to be well fed given their height, but are not as tall as those in the references. However, these results are neither necessary nor sufficient to rule out the hypothesis that the genetic potential of the Indian population in terms of height is the same as in the reference population. On the one hand, differences in genetic potential could explain at least part of the figures in Table 4. On the other hand, there are obviously many factors, besides parental education and asset ownership, which are important determinant of height, and which are not adequately taken into account in the tabulations above. For instance, both feeding practices and the epidemiological environment, with its impact on infections, are crucial for child development. Another factor which may help explaining the figures in Table 4 is that it may take several generations for anthropometric outcomes to catch up to the genetic potential. For instance, well-off mothers who grew up in poverty are more likely to be smaller and to give birth to smaller children than women who grew up in a resource-abundant environment. Such mechanism will likely lead to inter-generational transmission of below-reference anthropometric outcomes.[19]

4 Growth Performances of Indians living in the United Kingdom

We continue the analysis of the genetic potential for growth of Indians by examining the nutritional status of individuals of Indian ethnicity living in a rich "Western" country, namely the United Kingdom (UK). We use data from the 1999-2000 round of the Health Survey for England (HSE), described in Section 2. One of the specific aims of this survey was the analysis of health, including anthropometric performance, among households belonging to the most populous six minority ethnic

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[19] I am grateful to John Komlos for pointing out this latter factor.

groups: Black Caribbean, Indian, Pakistani, Bangladeshi, Chinese and Irish. The sample includes 1,668 ethnic Indians, but we also use the information on other South Asian immigrants, which adds to the sample 2,013 Pakistanis and 1,830 Bangladeshis.

A comparison between the anthropometric performances of children within this sample and those in the NFHS would not be very informative, because HSE includes a very small number of U3s, the relevant age group in the 1998-99 NFHS. In HSE, height and weight were not measured for children below 24 months of age, the number of children of South Asian and Indian ethnicity which are less than three-year old is very small, and their height and weight are sometimes missing. However, we are more broadly interested in the relative performance of children of Indian or South Asian ethnicity living in the UK, so we can also use the information available for older children. Table 5 summarizes the age distribution in the 1999-2000 HSE for each South Asian ethnic group. For all ethnic groups, the fraction born outside the UK increases with age. The new WHO-2006 charts are only constructed for children under five (U5), and the HSE sample includes only 89 such children of Indian ethnicity. For the purpose of allowing the use of information from older children, we therefore complement the analysis with results obtained by using the new CDC-2000 charts described in the introduction.

Table 6 shows sample median height-for-age and weight-for-height z-scores, as well as the prevalence of stunting and wasting, by minority group, for different age ranges. For reference, we also show the results for children of "white" ethnicity. All statistics are calculated both using the new WHO-2006 standards and the revised CDC-2000 charts. WHO References for children older than five years are not available, and the same holds for weight-for-height in the case of CDC charts.

Using either references, the median height-for-age z-score for the ethnic Indian children in the sample is close to zero, regardless of the age group considered. Similarly, the proportion of stunted and wasted children is always close to zero.[20] None of the Indian children are wasted and the proportion who is stunted is, at most, close to 5%. The extent of stunting is similarly low for ethnic Pakistani and among younger Bangladeshi children. The inclusion of children up to 18 years old brings the proportion of stunted ethnic Bangladeshi children up to 9%. Almost no ethnic Indian child in the sample is wasted, while the corresponding proportion among other ethnic South Asians ranges from zero for 2 to 3 year old Pakistanis and Bangladeshis to 9% among 2 to 5 year old Bangladeshis.

Overall, these results provide some *prima facie* evidence in support of the hypothesis that the

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[20] Note that if z-scores in the reference population are distributed normally, the fraction of stunted and wasted children in such population will be equal to 0.025.

growth performance of children of Indian ethnicity who live in the UK is comparable to that of the reference population used to construct either the WHO-2006 or the CDC-2000 references. Of course, these findings are not sufficient to disprove the claim that genetic factors play a role in explaining the relative disadvantage in growth pattern of children, such as those sampled within the NFHS, who are born and raised in India. To argue that ethnic Indians who live in the UK share the same genetic characteristics in terms of growth potential as their counterparts still living in India, one should argue that migration to the UK is uncorrelated with growth potential. However, there are reasons to suspect that correlation may exist, as migrants are often taller.

South Asians who migrate to the UK are relatively skilled, as shown in Table 7, in which we decompose individuals born abroad by occupation type.[21] Among ethnic Indians, about one half of the sample is composed of skilled non-manual, managerial or professional workers. Semi-skilled or unskilled work form only one quarter of the sample.[22] Such distribution of skills is clearly very different from that observed in India, where the share of the labor force employed in unskilled occupations remains very high. There is also a significant gap between the *adult* height of Indians living in the UK and that of individuals still residing in India. According to the 77,487 observations from the 1998-99 NFHS, the mean height of (ever married) women of age 20 to 49 was 151.3 cm (standard error 0.041) while the mean height of the 407 ethnic Indian women in the same age group in the HSE sample was 157 cm (standard error .35). The NFHS does not report height for males, but data on the height of adult males have been estimated using survey data collected in 2000-2001 by the Indian National Institute of Nutrition (National Nutrition Monitoring Bureau 2002). This survey, carried out in rural areas of the states of Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu and West Bengal, also included height measurements of 7,577 males and 12,917 females of age 18 to 44. In this sample, mean height was 151.1 cm for women, and 163.3 for men.[23] The latter figure is significantly lower than the mean height of the 310 Indian men of age 18 to 44 measured in the HSE, which is equal to 171.3 cm (standard error .37).[24]

The tabulations in Table 7 show the existence of a correlation between labor market skills and

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[21] The tabulation is almost identical if we include only individuals who migrated after age 18, for whom schooling was already largely completed.

[22] Note also that low-skill workers are much more common among Bangladeshi immigrants, a finding which is likely related to the relatively low growth performance of children of this ethnic group, as shown in Table 6.

[23] The source of these figures is Table An-38 and An-39 in National Nutrition Monitoring Bureau 2002, which can be accessed at `http://www.nnmbindia.org/NNMBREPORT2001-web.pdf`.

[24] For this same age group, mean height for women as calculated with HSE data was 157.3 (standard error .36).

probability of migrating to the UK. If genetic *potential* in terms of height were correlated with ability, and hence with outcomes such as schooling achievements and earnings ability, the pool of ethnic Indians living in the UK would likely overstate the height potential of non-migrating Indians. Such correlation may exist. However, it has not been demonstrated, unlike the correlation between *actual* height and measures of ability and economic well-being, which has been solidly documented, both in developing and in rich countries (for reviews, see Steckel 1995, Strauss and Thomas 1998, Komlos and Baur 2004, Komlos and Lauderdale 2007, Strauss and Thomas 2008). In developing countries, a larger body size is often associated with higher earnings in occupations which require physical strength (Haddad and Bouis 1991). Researchers have also argued that taller individuals may earn more because being taller increases self-esteem and status, facilitates social interactions during youth, and is associated with better cognitive ability because of factors such as better childhood nutrition (Persico et al. 2004 and Case and Paxson 2006).

Further evidence on the relevance of the socio-economic environment for growth can be derived studying the relation between height, age and year of migration into the UK. Specifically, suppose that Indian immigrants are taller than their countrymen still living outside the UK not (or not only) because of genetic factors but because of better socio-economic conditions in the UK. Then we should expect individuals who have spent a larger fraction of their lives in India to have worse growth performance than others who were born in the UK, or who lived there most of their life. To evaluate this hypothesis, we estimate the following equation using information for all individuals of age below 50:

$$\ln h_i = F_i \times \phi_F(age_i) + (1 - F_i) \times \phi_M(age_i) + (\beta_1 + F_i\beta_2)\ln(pci_i) + (\beta_3 + F_i\beta_4)S_i + u_i, \qquad (2)$$

where h_i is height (in centimeters) of individual i, F_i is a binary variable equal to one if i is a female, pci_i is household yearly income per head, $\phi_F(.)$ and $\phi_M(.)$ are unspecified functions of age and S_i is the fraction of years individual i lived outside the UK. We exclude individuals older than 50, for whom the relation between life spent outside the UK and height could be confounded by an additional factor: height begins to decline after such age threshold, and older individuals are more likely to have spent a larger fraction of their life outside the UK (see Table 5). Because the relationship between height and age is highly non-linear over the age range used here, we model its shape non-parametrically using a sieve estimator, using gender-specific sequences of basis functions to approximate the true shape of the conditional expectation.[25] Univariate regressions

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[25] We used 3rd order polynomial splines with 3 knots as the sieve basis. For a simple introduction to sieve estimation, see Pagan and Ullah 1999, Section 3.8.

of (log) height on these basis functions (not reported here) show that the curves estimated non-parametrically approximate very well the shape of the relationship between height and age. We control for income because the number of years spent outside the UK is likely correlated with earnings. Total annual income is reported in the HSE in intervals, rather than as a continuous variable. More specifically, income is recorded to be below £520, or more than £150,000, or within one of twenty-nine intermediate categories. Instead of including in the regression a large number of income dummies, we transform the data assuming that income is equal to the mean of the bracket boundaries. For the handful of observations for which income is more than £150,000, we impute a value equal to 150,000. We estimate the standard errors allowing for intra-household correlation of the errors u_i.

In Table 8 we estimate equation (2) separately for three different samples: all individuals of South Asian ethnicity (that is, individuals born in Bangladesh, India or Pakistan, Column 1), ethnic Indian only (column 2) and ethnic Bangladeshi and Pakistani only (column 3). In all regressions, and for both males and females, the fraction of life spent abroad is negatively associated with height, although when only ethnic Indians are included the corresponding coefficients are smaller and not statistically significant. When all ethnic South Asian are included, the slope for males (β_3) is equal to $-.011$ and significant at the 5% level, while for females the slope ($\beta_3 + \beta_4$) is almost twice as large and significant at the 1% level. Given that the dependent variable is in logarithms, these estimates imply, for instance, that conditional on age and income per capita, a male in the sample who has spent half of his life outside the UK has a predicted height .55% lower than a male who has spent his whole life in UK. For females, the predicted difference is .95%. The magnitude of these estimates is not negligible. For instance, a .95% difference in height for a woman who is 160 cm tall is 1.52 centimeters. These estimates are also large relative to the standard deviation of the dependent variable, which is .111 and .084 for males and females respectively for all ethnic South Asian, and .096 and .076 respectively for ethnic Indians. The results for ethnic Indians still indicate a negative association between height and time spent outside the UK, but the coefficients are smaller and not significant. When only ethnic Bangladeshis and Pakistanis are included, the slopes are similar to those obtained for all South Asians, but the difference in slopes between females and males increases from 0.008 to 0.013.[26] Overall, these results suggest that factors such as socio-economic conditions and medical services, which are better in the UK than in the immigrants' country of origin, are positively associated with height.

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[26] If individuals older than 50 are included, the estimated slopes $\hat{\beta}_3$ and $\hat{\beta}_4$ become larger (in absolute value) and more significant. These results are available upon request from the author.

5 Conclusions

In this paper we have evaluated the growth performance of Indian children of age 0 to 3 using data from the 1998-99 National Family and Health Survey, making use of the new standards developed by the World Health Organization's Multicentre Growth Reference Study. We find that the new charts lead to an increase of 4.2 million in the estimated number of stunted children, and of 2.3 million in the number of wasted children. However, the number of underweight children *decreases* by 2.1 million, mostly through the impact of the new charts on girl indices.

These results strongly suggest that the relative magnitude of different measures of nutritional status is affected by the choice of reference. This also confirms that different anthropometric indices are not perfectly correlated, so that to assess the nutritional status of a population it is useful to analyze more than one such index. This is *not* the approach chosen for the Millennium Development Goals, for which underweight is the only anthropometric index selected to assess progress towards the goal of halving U5 malnutrition by 2015.[27]

We also use data on ethnic Indians living in the United Kingdom to contribute evidence in favor of the hypothesis that commonly used growth reference standards are appropriate for the Indian population. We find that children of Indian ethnicity who live in the UK have anthropometric outcomes comparable to those in the WHO-2006 standards. We also find that, even after controlling for income per head, the height of ethnic Indians in the sample is positively related with the amount of time spent in the UK. Overall, these findings are consistent with the argument that socio-economic and epidemiological factors, and not genetic differences, are the major causes of the relatively poor growth performance in India. However, the evidence provided here cannot be deemed conclusive, because the genetic pool of Indians who migrated to the UK does not necessarily coincide with that of others who remain in India. At the same time, this paper contributes to a literature that show how individuals that migrate from poor to developed countries are usually characterized by better growth patterns than their same-ethnicity counterparts who do not migrate (Yip et al. 1992, Duggan and Harbottle 1996, Mei et al. 1998, Smith et al. 2003 Nguyen et al. 2004).

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[27] See `http://www.mdgmonitor.org/goal1.cfm`.

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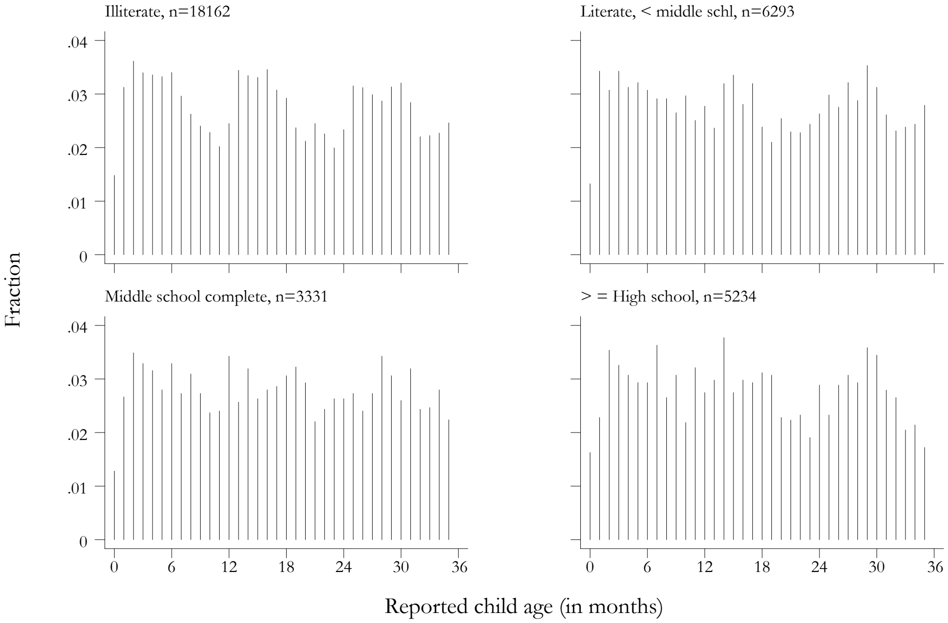

Figure 1: Empirical distribution of reported age (in months), by mother's education attainment. Source: NFHS 1998-99.

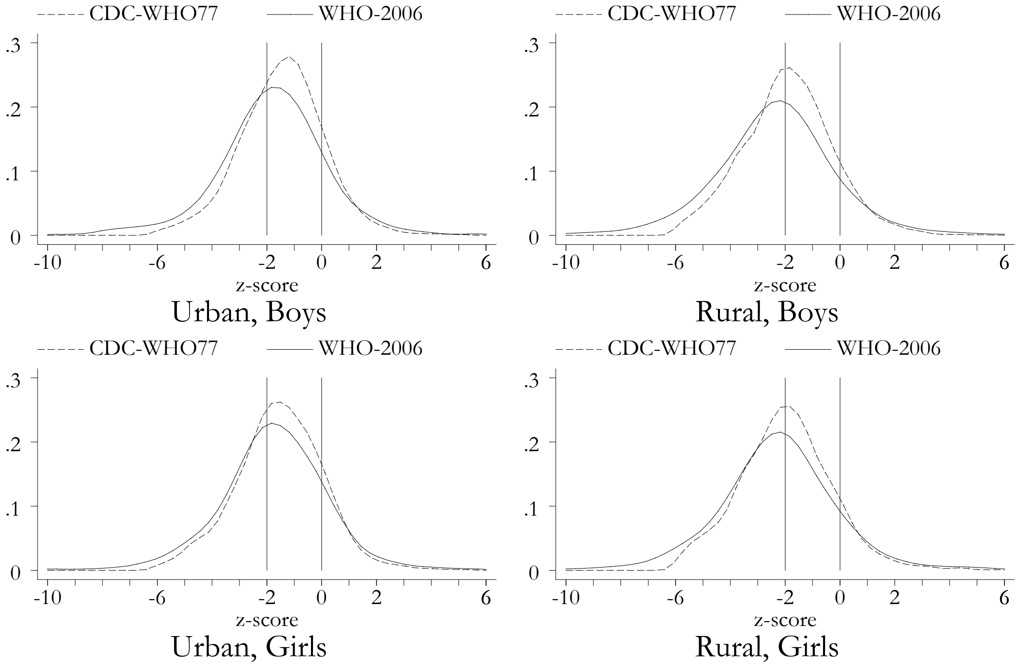

Figure 2: Height-for-Age, All India, 1998-99: densities estimated using Kernels. Curves labeled "CDC-WHO77" are constructed with the z-scores originally included in NFHS, which use the CDC-WHO77 references; "WHO-2006" curves use weight and height data from NFHS and WHO-2006 references.

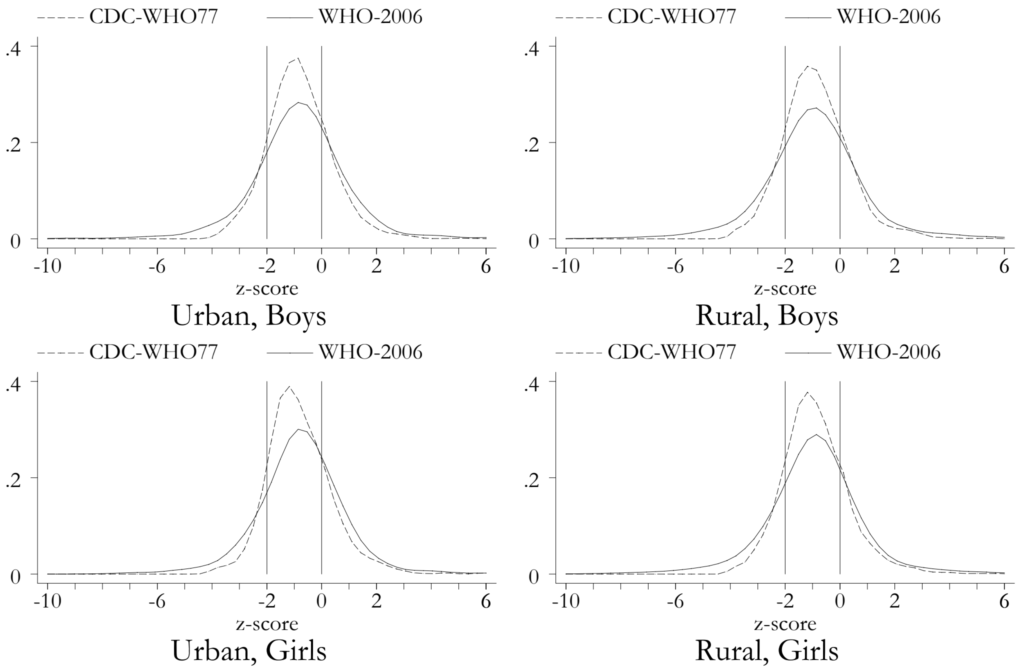

Figure 3: Weight-for-Height, All India, 1998-99: densities estimated using Kernels. Curves labeled “CDC-WHO77” are constructed with the z-scores originally included in NFHS, which use the CDC-WHO77 references; “WHO-2006” curves use weight and height data from NFHS and WHO-2006 references.

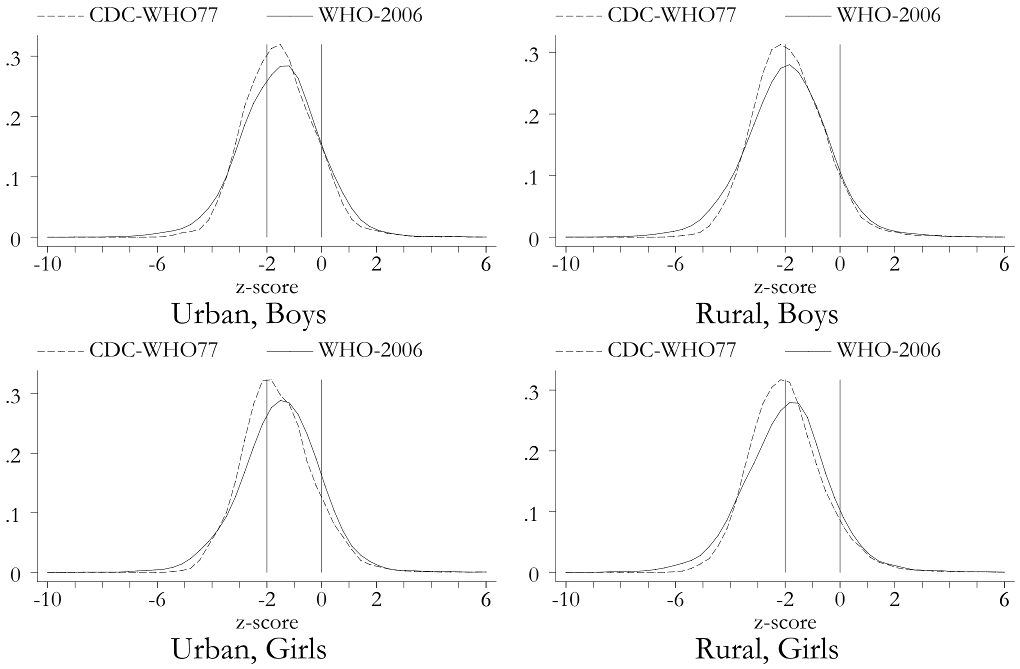

Figure 4: Weight-for-Age, All India, 1998-99: densities estimated using Kernels. Curves labeled “CDC-WHO77” are constructed with the z-scores originally included in NFHS, which use the CDC-WHO77 references; “WHO-2006” curves use weight and height data from NFHS and WHO-2006 references.

Table 1: Summary Statistics: Women, NFHS 1998-99

	Rural	Urban
Number of women (total)	62,248	28,055
Number of women with at least one U3 child	20,493	7,293
Household size	7.7 (3.9)	7.4 (4.0)
No. of children below age 3	1.11 (.31)	1.12 (.32)
Proportion of girls below age 3	.48 (.49)	.48 (.48)
Illiterate	.65 (.48)	.34 (.47)
High school diploma or above	.09 (.29)	.34 (.47)
Working (for others or self-employed)	.21 (.41)	.15 (.35)
Hemoglobin level (g/dl)	11.4 (1.81)	11.8 (1.74)
Anemic (hg$<$ 12)	.59 (.49)	.50 (.50)
Height (in cm.)	151.0 (6.3)	151.5 (6.6)
BMI (kg/h^2)	19.2 (2.6)	20.6 (3.7)
BMI $<$ 18.5	.43 (.50)	.31 (.46)

Source: Author's calculations from NFHS 1998-99. All means refer to ever married women of age 15-49 with at least one U3 child, and are calculated using sampling weights. Standard deviations in parenthesis.

Table 2: Stunting and Wasting: NFHS 1998-99

	(1)	(2)	(3)	(4)	(5)	(6)
	Boys		**Girls**		All	
	$P(y \leq 2)$	$P(y \leq 3)$	$P(y \leq 2)$	$P(y \leq 3)$	$P(y \leq 2)$	$P(y \leq 3)$
Urban	pop.≈8.05		pop.≈7.5		pop.≈15.55	
Reference			Height-for-Age			
CDC-WHO77	0.34	0.14	0.37	0.17	0.35	0.16
WHO-2006	0.44	0.23	0.43	0.23	0.44	0.23
WHO-2006 (truncated)	0.42	0.20	0.41	0.20	0.42	0.20
			Weight-for-Height			
CDC-WHO77	0.14	0.03	0.12	0.02	0.13	0.03
WHO-2006	0.18	0.07	0.17	0.06	0.18	0.07
WHO-2006 (truncated)	0.16	0.04	0.15	0.03	0.16	0.04
			Weight-for-Age			
CDC-WHO77	0.37	0.11	0.40	0.12	0.38	0.11
WHO-2006	0.36	0.13	0.34	0.13	0.35	0.13
WHO-2006 (truncated)	0.36	0.12	0.34	0.12	0.35	0.12
Rural	pop.≈27.7		pop.≈25.9		pop.≈53.6	
Reference			Height-for-Age			
CDC-WHO77	0.47	0.24	0.50	0.27	0.48	0.25
WHO-2006	0.57	0.35	0.56	0.34	0.57	0.35
WHO-2006 (truncated)	0.55	0.32	0.54	0.31	0.55	0.32
			Weight-for-Height			
CDC-WHO77	0.16	0.03	0.16	0.03	0.16	0.03
WHO-2006	0.23	0.10	0.22	0.09	0.23	0.10
WHO-2006 (truncated)	0.20	0.05	0.19	0.05	0.20	0.05
			Weight-for-Age			
CDC-WHO77	0.48	0.19	0.52	0.21	0.50	0.20
WHO-2006	0.48	0.21	0.47	0.22	0.48	0.21
WHO-2006 (truncated)	0.47	0.21	0.47	0.21	0.47	0.21
All India	pop.≈35.75		pop.≈33.4		pop.≈69.15	
Reference			Height-for-Age			
CDC-WHO77	0.41	0.19	0.44	0.22	0.42	0.20
WHO-2006	0.51	0.29	0.49	0.28	0.50	0.29
WHO-2006 (truncated)	0.48	0.26	0.48	0.26	0.48	0.26
			Weight-for-Height			
CDC-WHO77	0.15	0.03	0.14	0.02	0.15	0.03
WHO-2006	0.21	0.08	0.19	0.07	0.20	0.08
WHO-2006 (truncated)	0.18	0.05	0.17	0.04	0.18	0.05
			Weight-for-Age			
CDC-WHO77	0.42	0.15	0.46	0.17	0.44	0.16
WHO-2006	0.42	0.17	0.41	0.17	0.42	0.17
WHO-2006 (truncated)	0.42	0.16	0.40	0.17	0.41	0.16

Source: NFHS 1998-99. Children of age 0-3 born from women of age 15-49. All estimates use sampling weights. The population figures (in millions) are calculated assuming a total Indian population of one billion, and estimating the fraction in each specific demographic group using the data in NFHS. Figures in rows denoted CDC-WHO77 include estimates that use the z-scores provided in the NFHS data set, which are calculated using CDC-WHO77 references, and using the truncation rule indicated in the text. WHO-2006 refer to figures calculated using the new WHO-2006 references, with or without adopting the same truncation rule as in NFHS.

Table 3: Stunting, Wasting and Underweight, by Standard of Living Index

	(1)	(2)	(3)	(4)	(5)	(6)
	% Stunted		% Wasted		% Underweight	
	Boys	Girls	Boys	Girls	Boys	Girls
Standard of Living Index						
Low	0.62	0.59	0.28	0.26	0.56	0.54
Medium	0.53	0.53	0.20	0.19	0.44	0.43
High	0.37	0.34	0.15	0.13	0.25	0.23

Source: Author's calculations from NFHS 1998-99. Children of age 0-3 born from women of age 15-49. All estimates use sampling weights. The Standard of Living Index is constructed assigning scores to a list of physical asset ownership indicators (see the NFHS final reports for details). All calculations are based on z-scores calculated with WHO-2006 charts.

Table 4: Z-scores: Children from Better-off households

	Mean	s.e.	Median	$P(y \leq -2)$	$P(y \leq -3)$
Height-for-Age	-0.877	2.619	-0.861	0.199	0.092
Weight-for-Height	0.105	2.377	-0.175	0.088	0.020
Weight-for-Age	-0.198	2.683	-0.417	0.094	0.019

Source: NFHS 1998-99. Children aged 0-35 months of both genders born from women of age 15-49. All estimates use sampling weights. The sample includes 212 children from relatively well-off families (see text for details on how these are defined). All calculations are based on z-scores calculated with WHO-2006 charts.

Table 5: Age Distribution by Ethnicity

	Age Group			
	$2 \leq age < 5$	$5 \leq age < 10$	$10 \leq age < 18$	$age \geq 18$
Indian	89	149	240	1,177
% born outside UK	4.5	2.7	3.8	76.6
Pakistani	212	270	376	1,149
% born outside UK	3.8	5.2	10.6	72.8
Bangladeshi	181	250	390	1,002
% born outside UK	6.1	10.4	31.3	91.2

Source: HSE 1999-2000.

Table 6: Anthropometric Outcomes of 2 to 18-year Old Children in the UK, by Ethnicity: 1999-2000

	Age Group (years)							
	$2 \leq age < 3$			$2 \leq age \leq 5$			$2 \leq age \leq 18$	
	WHO	CDC	n	WHO	CDC	n	CDC	n
Height-for-Age								
				Median z-scores				
White	-0.009	0.217	24	-0.034	0.240	100	0.100	528
Indian	0.345	0.572	19	-0.197	0.100	72	-0.191	471
Pakistani	-0.320	-0.104	49	-0.026	0.264	162	-0.088	820
Bangladeshi	-0.574	-0.295	40	-0.394	-0.082	140	-0.520	786
				Proportion Stunted				
White	0.000	0.000	24	0.010	0.010	100	0.019	528
Indian	0.053	0.053	19	0.042	0.042	72	0.049	471
Pakistani	0.020	0.020	49	0.038	0.025	162	0.030	820
Bangladeshi	0.025	0.025	40	0.050	0.043	140	0.094	786
Weight-for-Height								
				Median z-scores				
White	1.053	0.723	24	0.886	0.713	94		
Indian	0.844	0.572	18	-0.008	-0.180	70		
Pakistani	0.607	0.291	46	0.575	0.372	156		
Bangladeshi	0.184	-0.190	32	0.355	0.122	113		
				Proportion Wasted				
White	0.000	0.000	24	0.000	0.000	94		
Indian	0.000	0.000	18	0.000	0.029	70		
Pakistani	0.000	0.065	46	0.006	0.051	156		
Bangladeshi	0.000	0.063	32	0.035	0.088	113		

Source: HSE 1999-2000. The z-scores are calculated using either the new WHO-2006 references ("WHO") or the revised CDC-2000 charts ("CDC"). Cells are empty when the corresponding growth charts are not available for the whole relevant age group.

Table 7: South Asian Immigrants Occupation Types

	Indian	Pakistani	Bangladeshi
Professional	10.6	6.26	1.65
Managerial technical	24.79	16.69	5.95
Skilled non-manual	9.23	9.39	6.06
Skilled manual	28.72	36.38	37.22
Semi-skilled manual	22.91	27.64	38.99
Unskilled manual	2.74	2.61	7.38
Not fully described	1.03	1.04	2.75
obs.	585	767	908

Source: 1999-2000 HSE. The figures indicate the proportion of working individuals in each occupational category, by ethnicity.

Table 8: Height and Fraction of Life Spent Abroad

		(1) South Asia	(2) India	(3) Bangladesh & Pakistan
β_1	ln(income per head)	0.008	0.007	0.008
		[0.001]***	[0.003]***	[0.002]***
β_2	Female×ln(income per head)	-0.003	0.000	-0.004
		[0.002]	[0.003]	[0.002]*
β_3	Fraction of life outside UK	-0.011	-0.005	-0.012
		[0.005]**	[0.008]	[0.006]**
β_4	Female×(Fraction of life outside UK)	-0.008	0.002	-0.013
		[0.006]	[0.014]	[0.007]*
Observations		3241	955	2286
R-squared		0.93	0.92	0.93
P-value: $H_0 : \beta_3 + \beta_4 = 0$		0.000	0.789	0.000

Source: 1999-2000 HSE. All regressions include a gender-specific cubic spline in age. Only individuals up to 50-year old are included. The regression in column (1) includes observations from ethnic Bangladeshis, Indians and Pakistanis. Estimated coefficients are statistically significant at 10% level if denoted by *, at 5% if labeled by **, and at 1% if labeled by ***. Standard errors are adjusted for intra-household correlation.