# Height, health, and development

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Adult height is determined by genetic potential and by net nutrition, the balance between food intake and the demands on it, including the demands of disease, most importantly during early childhood. Historians have made effective use of recorded heights to indicate living standards, in both health and income, for periods where there are few other data. Understanding the determinants of height is also important for understanding health; taller people earn more on average, do better on cognitive tests, and live longer. This paper investigates the environmental determinants of height across 43 developing countries. Unlike in rich countries, where adult height is well predicted by mortality in infancy, there is no consistent relationship across and within countries between adult height on the one hand and childhood mortality or living conditions on the other. In particular, adult African women are taller than is warranted by their low incomes and high childhood mortality, not to mention their mothers' educational level and reported nutrition. High childhood mortality in Africa is associated with taller adults, which suggests that mortality selection dominates scarring, the opposite of what is found in the rest of the world. The relationship between population heights and income is inconsistent and unreliable, as is the relationship between income and health more generally.

income | mortality | Africa | nutrition | childhood

**F**ogel (1, 2) has been a pioneer in the study of the two-way links between income and health, and height has been one of his most effective instruments in that study. He and Costa (3) describe "techno-physio evolution," "a synergism between technological physiological improvements that is biological but not genetic, rapid, culturally transmitted, but not necessarily stable" (ref. 2, p. 20). During techno-physio evolution, both people and the economy grew in tandem, economic growth both permitting physiological growth, through better nutrition, and depending on it, through the enhanced ability of taller and stronger people to work. Height is an indicator of health that is useful in historical work, because it is often available when there is little or no other information on morbidity or even mortality. It is also directly relevant for those aspects of health that make for higher economic output. Taller individuals earn more, either because they are physically more capable of work (4) or because height is an indicator of higher cognitive potential in the sense that people who do not reach their full genetic height potential probably do not reach their full genetic cognitive potential either (5).

Height is determined by genetic potential and by net nutrition, most crucially by net nutrition in early childhood. Net nutrition is the difference between food intake and the losses to activities and to disease, most obviously diarrheal disease, although fevers or respiratory infections also carry a nutritive tax. In consequence, adult height is an indicator of both the economic and disease environment in childhood. As such, it is at least a partial indicator of the health component of well being. Because of the link to gross nutrition, and because, particularly in poor countries, gross nutrition is tied to income, the link from income per head to gross nutrition and population height has often been used by historians as an indicator of the material standard of living, although the link is importantly contingent on the disease environment, most famously during the early industrial revolution in Britain.

Independently of links between height and economic outcomes, understanding the determinants of height is important for understanding health. On average, taller people live longer (6). The height-restricting biological responses to childhood nutritional insults and disease may have a short-run survival advantage but negative consequences in later life (7–9). In consequence, shorter people are more prone to chronic disease in late life and likely to die earlier. The cognitive disadvantages of these same insults will restrict educational opportunities, and both education and cognitive ability are well documented predictors of better health.

The restriction of height by malnutrition and disease may no longer be important in rich countries, but the process is certainly far from complete in poor countries, where infant and child mortality rates remain high, and average nutritional intake is low. In those countries, policy issues concerning growth and population health remain of great urgency. If health is a precondition for economic performance, direct improvement of health, through public health measures, child nutritional programs, immunization, and the provision of healthcare, is the immediate priority, not only for themselves, but also because they will also reduce material deprivation. If, on the contrary, economic growth will not only reduce poverty but also automatically improve population health, the immediate priority is to work on the preconditions for economic growth, such as investment, or institutional change. It is also possible that there are important third factors, such as education or the quality of governance, that are good for both health and economic growth, and that are responsible for the strong positive cross-country correlation between life expectancy and economic growth (10).

Here I examine international patterns of adult height, focusing on the links among adult height, disease, and national income. Although there is a large genetic component to heights within populations, the contribution of genetics to variation in mean heights across populations is much smaller. Indeed, the large increase in heights in Europe and North America over the last two centuries is clearly not driven by changes in gene pools, even those associated with migration, but by changes in the disease and nutritional environments. So the question arises whether the same is true across populations now, as well as over time within populations whose economic and disease environments are much less favorable than currently prevailing in the rich world.

I use data on the average heights of women for each birth cohort over most of the last half century, focusing on poor and developing countries. Nationally representative data on the height of women of reproductive age has recently become available for a substantial number of poor and middle-income countries through the Demographic and Health Surveys, and I use those data to describe international patterns of adult height.

## Materials and Methods

My analysis is conducted within a simple framework of scarring and selection. In the absence of disease or malnutrition, adult

height is selected from a parent distribution of heights, from which only those with height above a cutoff survive. The disease and nutritional environment in childhood is assumed to have two effects. First, a high-disease and low-nutritional environment increases the survival cutoff, so more children do not survive. This selecting of children with low potential adult height, as measured by mortality rates, increases the average adult height of the population. Second, I assume that the children who survive experience a reduction in their final adult height that depends on the severity of the disease and nutritional environment in childhood. This scarring effect reduces adult height among the survivors and works in the opposite direction to selection. Which effect predominates is an empirical issue, although, as shown in ref. 11, selection is likely to dominate when infant and child mortality is very high, with scarring predominating in richer low-mortality settings. Most studies find that scarring predominates over selection, so that I start from the presumption that high disease environments in childhood will reduce mean adult heights.

Within this general framework, my empirical analysis proceeds by linking adult height to measures of the disease and nutritional environment in childhood, here represented by infant and child mortality rates around the year of birth, as well as by income, typically represented by real per-capita income in purchasing power parity dollars.

The special nature of adult height makes it possible to construct long time series of observations from a single cross-sectional survey. Once an individual attains full adult height, around age 18 in contemporary rich societies, height does not change for the rest of life, although there may be some shrinkage in old age, and the average ages of those currently alive are also affected by height-selective mortality, as well as by immigration and emigration. Subject to those caveats, it is possible to use a survey collected at a single point in time to calculate average adult heights by year of birth, which can then be related to economic and health conditions in that year. In the historical literature, heights are usually measured for special samples, often from military conscripts, but in recent years, there have been an increasing number of national health surveys that have collected data on the heights of adults. I use the system of Demographic and Health Surveys, which, over the last decade or so, have begun to measure the heights of adult women aged 15–49.

Heights were measured, and data are currently available for 51 Demographic and Health Surveys from 43 countries in Africa, Latin America, and the Caribbean, South Asia, and Central Asia collected between 1993 and 2004 [Demographic and Health Surveys (DHS) Datasets; www.measuredhs.com]. Women aged between 15 and 49 (sometimes only ever-married women) were measured by the survey teams; survey-provided weights were used to make summary statistics representative of the national population of women of the relevant ages. The number of heights collected varies from nearly 84,000 in India to 891 in Comoros. With the smaller samples, I have only imprecise estimates of mean height by date of birth. For the three South Asian countries, Bangladesh, India, and Nepal, where levels of malnutrition are the highest in the world, women do not appear to reach their full adult height until their early 20s. Although adult heights are attained earlier elsewhere, I restrict the age range for calculating means and SDs to 25–50.

## Results

Preliminary inspection of the data shows that South Asian women are markedly shorter than other women; the population-weighted average of the three countries (Bangladesh, India, and Nepal) is 151.2 cm compared with 155.0 cm for Latin America and the Caribbean (14 surveys from eight countries: Bolivia, Brazil, Colombia, Dominican Republic, Guatemala, Haiti, Nicaragua, and Peru), 156.9 cm for five Central Asian countries
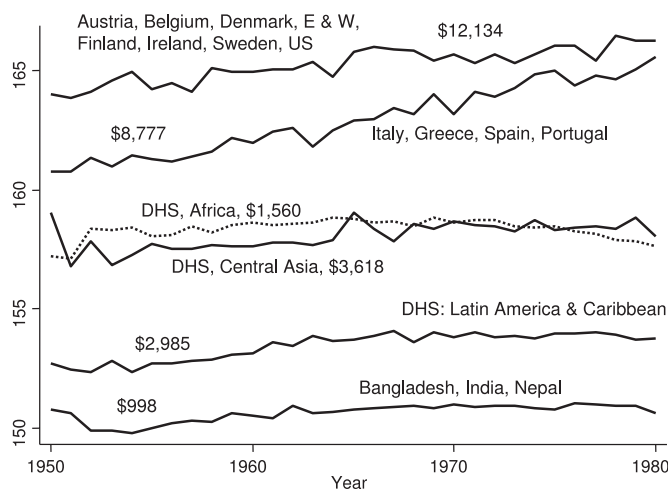


**Fig. 1.** Women's height by date of birth. Simple unweighted averages of country data within regions. The dollar figures are real (1996 international prices) GDP per capita in 1970 (chained) from the Penn World Table, Version 6.1.

(Armenia, Kazakhstan, Kyrgyz Republic, Turkey, and Uzbekistan), and 157.8 cm for Africa (29 surveys from 27 countries). Although Africans are taller overall, there is a good deal of variation across countries. Dispersion of height, as measured by the SD calculated for each country and then population weighted over countries within a region, is also lowest in South Asia (5.80 cm) followed by Central Asia (5.86 cm), Africa (6.58 cm), and Latin America and the Caribbean (6.81 cm). The regional (and indeed country) variation in dispersion is larger than the regional and country variation in heights, so that the lower SD in South Asia is not simply "explained" by its lower mean; the cross-survey regression of the logarithm of the SD of heights on the mean height has a coefficient of >1.5. Within each region, the dispersion in heights mostly reflects within-country dispersion; for example, in Africa, the overall variance in heights is 43.9 cm$^2$, of which fully 40.4 cm$^2$ is the within-country component. This dominance of within- over between-country variation has previously been noted for children's heights in ref. 12.

The lack of any obvious pattern in these means and variances presents a challenge to the view that population mean heights are predominately determined by economic and sanitary environments. Africa is the poorest of the regions and has the highest disease burden yet is the tallest of the regions.

Fig. 1 displays the height data by region and by date of birth within region. It also includes average heights for women for a group of European countries and the U.S. taken from ref. 11. In Fig. 1, I have calculated average heights by date of birth for each country and then averaged the averages over country within regions without weighting by country population or sample size. Here I am interested in the experience of each country as an example of all possible histories, not in trying to estimate the average heights by date of birth of all women in a region. For each country grouping, Fig. 1 also shows its per-capita gross domestic product (GDP) in 1970 in 1996 international dollars, taken from the Penn World Table. When country years (e.g., Armenia before 1992) are not available in the Penn World Table, they are dropped, and means are computed over all available countries.

With the exception of Africa, where women are tall relative to their national incomes, there is at least a gross interregional correspondence between height and income. Over time, as real incomes have grown, heights have grown, too. In the richer group of northern countries, heights grew until about the birth cohort of 1970, but there has been little growth since. In the poorer northern
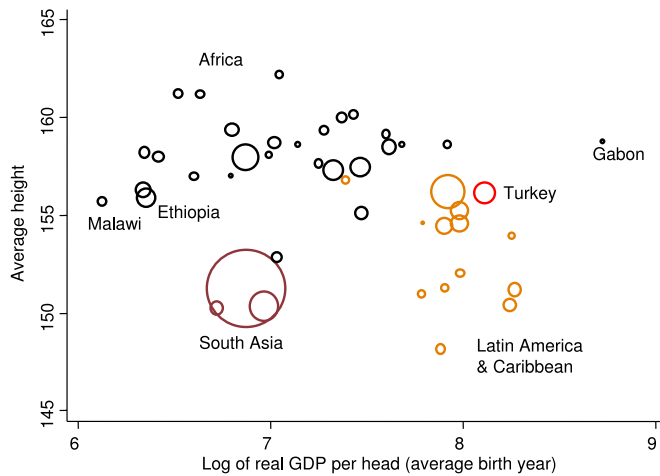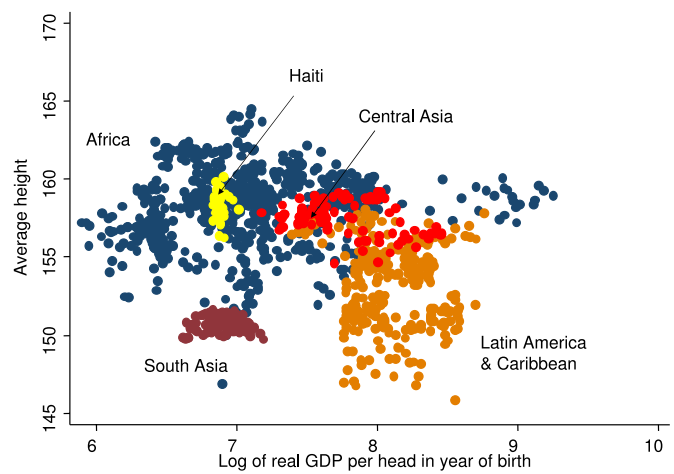
**Fig. 2.** Women's height and real per-capita income.



**Fig. 3.** Average height and child mortality.

group, growth in heights has been steady from 1950 through to 1980. In the other regions, the birth cohort of 1980 was taller than the birth cohort of 1950, with the exception of Africa. African heights have been falling since the mid-1960s and appear to have continued to fall in (fully mature) cohorts that have been born since 1980 (not shown in Fig. 1). The brief turndown in heights in South Asia up to 1980 does not indicate any change in trend but rather that women in the region do not attain their full adult height until their early 20s, so that the birth cohorts immediately before 1980 show artificially low average heights. Real incomes in the three South Asian countries have been growing rapidly relative to those in the African countries included in the DHS. Real per-capita incomes in Africa have been falling since 1980, and by 2000, the simple average of per-capita incomes in Bangladesh, India, and Pakistan was 10% higher than the simple average over the African countries.

Figs. 2 and 3 (which exclude the rich countries) show the difficulty of linking population heights to population differences in child mortality rates and to income. These figures plot for each country a circle with diameter proportional to the size of the country's population. In both cases, the *y* axis shows the average height of women aged 25–50 from the DHS. In Fig. 2, the *x* axis shows the logarithm of real per-capita GDP in the nearest year to the average date of birth of the women in the survey, typically a year in the 1960s. In Fig. 3, the *x* axis shows child mortality rate per thousand, again in the average year of birth. (The average year of birth is also used to calculate the population that determines the circle size.)
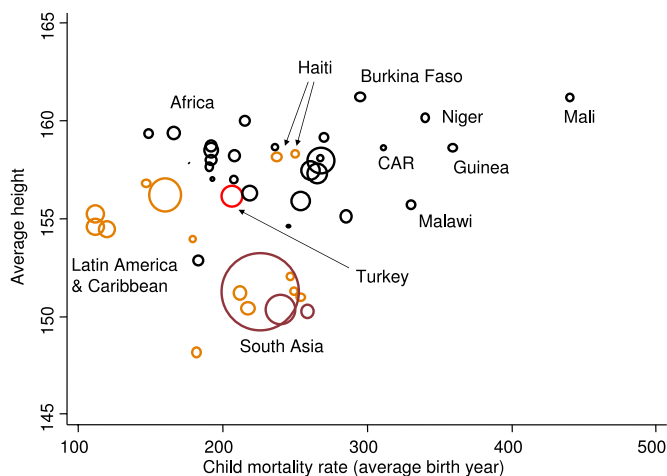
Because child mortality rates are available only for 1960, 1970, and 1980, I have interpolated between them to match the average year of birth. Each region is shown in a different color and, because of data limitations for the "new" countries of Central Asia, Turkey is the only representative of the region in the figures.

If height is determined in childhood by the availability of food, and if the availability of food is well proxied by income per capita, Fig. 2 should show a positive slope, as is the case across Europe and the U.S. (see ref. 11). Instead, the slope is negative; the (un-weighted) regression corresponding to Fig. 2 has a slope of −1.63 with a *t* value of −2.1, so that a doubling of income per capita is associated with a reduction of 1.63 cm in average women's adult height. If height is determined not by food availability but by the disease environment in childhood, Fig. 3 should show a negative slope, and once again, this prediction was verified for Europe and the U.S. in ref. 11. But the slope in Fig. 3 is small and positive; the regression slope is 0.012 with a *t* value of 1.7. Fig. 3 can be redrawn with infant, in place of child, mortality, and although the graph is somewhat different, the slope is virtually unchanged at 0.013 with a *t* value of 1.04.

The global failure of either income or the disease environment to predict mean adult height comes almost entirely from Africa, particularly the contrast between African countries on the one hand and the rest of the world on the other. Although most of the countries in the graphs are African, both Figs. 2 and 3 show that the relationships are mostly as expected in Latin America and the Caribbean, especially if Haiti is excluded, as well in the combined data of Latin America, the Caribbean, South Asia, and Turkey. But African women are tall, even in the poorest and most disease-ridden countries (top right of Fig. 3). Although these women may have been well nourished in childhood, they were so despite some of the world's lowest levels of national income per head.

Figs. 2 and 3 use only one observation per country (or survey) and make no use of the variation of heights over dates of birth and the corresponding variation in incomes and childhood disease. Fig. 4 corresponds to Fig. 2 but now shows all individual observations for each country, so that each point shown is the average height of women in a specific birth cohort and country plotted against the logarithm of real national income in the year of birth. I have excluded average heights when the number of women in the average is <10 and, when I run regressions, I weight by the square root of the number of observations in the average to allow for the varying degrees of precision in these estimates.

Fig. 4 shows that, to a remarkable extent, the developing countries of the world are regionally separated in the space of income and mean height. And, although it is possible to see a weak association between height and income across the regions other



**Fig. 4.** Average height and real per-capita income in year of birth.

**Table 1. Regressions of height on real income and child mortality rates**

| | Log of per capita income | Child mortality rate | Region | Country | Number of observations |
|---|---|---|---|---|---|
| All regions | −1.31 (8.9) | — | — | — | 1,184 |
| | −0.29 (2.1) | — | * | — | 1,184 |
| | 0.11 (0.7) | — | — | * | 1,184 |
| | −1.11 (6.5) | 0.006 (3.9) | — | — | 1,144 |
| | −0.52 (3.3) | −0.002 (1.3) | * | — | 1,144 |
| | 0.75 (3.9) | 0.007 (6.9) | — | * | 1,144 |
| Ex-Africa | 0.61 (2.6) | — | — | — | 500 |
| | −2.53 (10.3) | — | * | — | 500 |
| | 0.85 (4.7) | — | — | * | 500 |
| | −0.25 (0.9) | −0.015 (5.4) | — | — | 500 |
| | −4.65 (24.0) | −0.031 (23.1) | * | — | 500 |
| | 0.11 (0.5) | −0.005 (4.5) | — | * | 500 |
| Africa | 0.61 (3.8) | — | — | — | 684 |
| | −0.54 (2.1) | — | — | * | 684 |
| | 0.80 (4.6) | 0.009 (7.2) | — | — | 644 |
| | 0.33 (1.3) | 0.018 (12.9) | — | * | 644 |

Information on child mortality rates is interpolated for birth years other than 1960, 1970, 1980, 1990, and 1995. Child mortality rates are expressed in deaths per 1,000 live births. All regressions are weighted by the square root of the number of observations in the height average for each date of birth. Means based on <10 observations are dropped. The numbers in parentheses are absolute *t* values.
*A set of region or country dummies was included in the regression.

than Africa, there appears to be no association either within Africa or between Africa and the other regions. Note too the extent to which Haiti looks like an African, not a Caribbean or Latin American, country.

The rich countries are excluded from Fig. 4, although it is clear what would happen if they were included. There would be another "block" of data at the top right of Fig. 4, which, if we forget what we are looking at, would "improve" the all-country relationship between height and income. Yet it would do nothing to establish such a relationship across or within the countries currently shown.

Table 1 uses the developing country data to estimate a set of regressions in which average height is related to income and child mortality rate. When the columns "region" and "country" show a star (*), the corresponding regression contains a set of regional dummies (for Africa, Central Asia, South Asia, and Latin America) or a set of country dummies, one for each country. With regional dummies, the regressions use only variation within countries and regions; with country dummies, the regressions use only variation within countries. In the first row, which corresponds to fitting a regression line through Fig. 4, height is negatively and significantly related to income. This negative effect is smaller, but still significant, if regional dummies are included in the regression, and becomes positive and insignificant when country dummies are included. So the failure for richer countries and regions to be taller than poorer countries and regions also holds within countries over time. When all of these countries are pooled together, and we look only within countries, there is once again no significantly positive relationship between height and economic success. These inconsistent patterns are not much changed when I add the child mortality rate to the regressions. Child mortality is normally expected to decrease height, because of the predominance of the scarring effects of high disease environments in childhood, but the effect is estimated to be positive when all data are pooled and positive when we look only within countries in the bottom row. The effect is insignificant and negative when only regional dummies are included. (Note that, because the child mortality data are interpolated, these regressions exaggerate the true amount of information and will exaggerate the absolute size of the *t* values. Regressions that retain only the noninterpolated values of child mortality rates for 1960, 1970, 1980, and 1990 show very similar patterns with smaller *t* values, which are now underestimated, because I am discarding genuine information on incomes.)

If Africa is excluded, the regression of height on income has a positive slope, as is to be expected from Fig. 4. But the estimate changes sign when regional dummies are included, and changes back to a significant positive effect when country dummies are included. In the non-African regions of the world, people get taller with higher incomes, although the cross-country effect within regions does not conform to this within-country effect. For the countries of Africa alone (Table 1 bottom), the cross-country effect of income is positive (richer countries are taller), but the within-country effect is (marginally) significantly negative.

Once again, including child mortality does nothing to clarify the pattern, although, as before, the non-African patterns are slightly more palatable, with child mortality negatively associated with heights in all three regressions. But even in those cases, the income effects are either insignificant or of the wrong sign, or both. In Africa, child mortality is positively associated with heights; conditional on income, which has the expected positive effect, children in countries with the highest disease burden turned into the tallest adult women. These regressions can be run with infant mortality in place of child mortality, and the results are virtually identical and are not shown.

Whatever determines adult height in these countries, it is neither income per head in childhood nor the disease burden in childhood as measured by either infant or child mortality. Such relationships as exist in the data are inconsistent within and between countries, or across regions of the world, so that even if further research were to make sense of one or the other of those regressions, we would still not have a story linking height to income or disease that is consistent within and across countries. One possibility, suggested by the last line of Table 1, is that in Africa, where child mortality is very high, selection predominates over scarring, so that both income and child mortality are positively associated with height. In rich countries, at much lower levels of mortality, scarring predominates. Yet this explanation does nothing to explain the perverse or insignificant effects of income in the non-African countries in Table 1.

## Discussion

Perhaps the major puzzle is why Africans are so tall. They have low income, in some cases as low as that of any population in history. Uganda's per-capita GDP in 1960 was $560 in 1996 real purchasing-power prices, and this figure is arguably only a few percent higher than the lowest sustainable level of GDP per

head, defined as the level that is (*i*) lower than any ever observed, (*ii*) lower than even the lowest poverty lines in the world's poorest countries and inconsistent with adequate nutritional intake, and (*iii*) lower than the standard of living at which the population is healthy enough to reproduce and grow (13). Yet women born in Uganda in 1960 had adult heights of 159 cm on average, fully 8 cm taller than Indian women born in the same year, in a country whose per-capita income was 150% of that of Uganda. African countries also bear an extraordinarily high burden of disease. In Mali in 1960, median life expectancy was 5 years; half of all children died before their fifth birthday. Yet the surviving women reached an average height of 162 cm in adulthood, taller not only than Indian women of the same cohort but also than Colombian women born in 1960, whose average adult height was 154 cm, and whose childhood mortality rate was 125 per thousand, only one-quarter of the rate in Mali. These selected examples are not exceptions to the rule, because there is no rule.

What other factors might account for international differences in height? One possibility is that income per capita is not a good indicator of nutrition. Africa is well endowed with land relative to its population, so nutrition might be relatively plentiful, despite low national income. The contrast between Africa and South Asia would then be between, on the one hand, high disease burden but good nutrition and, on the other, low disease burden but poor nutrition. If nutrition is the main determinant of height and disease burden the main determinant of child mortality, we would have a possible explanation of the height and mortality pattern between Africa and Asia. The data on nutrition are less plentiful than the data on income, but the United Nations Food and Agriculture Organization (FAO) publishes a nutritional database (14) that gives per-capita calorie availability for most of the countries considered here for the years 1970, 1980, and 1990. A plot of average height against calorie availability looks very much like Fig. 4, albeit with fewer points. There are many African countries whose women are tall, even though there was very low calorie availability in the year of their birth. The worst example is Chad, where the FAO estimates a per-capita calorie availability of 1,640 around 1980, one of the lowest numbers ever recorded (see again ref. 12). Yet the adult height of women born in that year was 164 cm. As in the case of income, there is a weak positive correlation between average height and calories if we exclude Africa, but that correlation does not show up consistently in regressions.

The literature on child malnutrition often identifies the mother's education as a key positive factor, so I have also looked for a relationship between heights and average years of women's education using data from ref. 15. This experiment foundered in exactly the same way as the others; women in many African countries are tall, and not only were their parents poor, malnourished, and at high risk of disease, but their mothers had almost no education. Once again, we get a picture like Fig. 4, where the raw correlation is negative, and where more sophisticated regressions, either with education alone or with education in combination with other factors, show inconsistent results across and between regions and countries.

The African puzzle will get worse in the future. Over the last 15 years, the combination of historically rapid Indian economic growth and African stagnation and decline has reversed the relative incomes shown in Fig. 1. In 1960, the African group shown here had an (unweighted) average income per head of $1,259 compared with $894 for the South Asian group (in 1996 real purchasing power parity international dollars.) By 1980, the figures were $1,740 and $997, so that the pro-Africa gap had widened. By 2000, the African mean had fallen to $1,704 and is below the 2000 Asian mean of $1,874. Although we do not know the adult heights of children born in 2000, we do know the heights of the children of that cohort, and that those heights are excellent predictors of future adult height. And the data show that the prevalence of stunting, the fraction of children whose height for age is >2 or 3 SD below the norm, remains much higher in South Asia than in Africa. DHS surveys from the late 1980s and early 1990s show that the prevalence of severe stunting (>3 SD below the norm) is 25.7% in South Asia and 13.9% in Africa and of moderate and severe stunting (>2 SD below) is 44.8% and 32.8%, respectively (16). The most recent data in the World Health Organization's global database on child growth and malnutrition (17) shows that, although child stunting in India is currently less prevalent than in a few African countries, such as Angola and Mali, it is much more prevalent than in most of them, including, for example, Benin, Botswana, Burkina Faso, Cameroon, Chad, Comoros, Uganda, and Zimbabwe. Yet in the late 1990s, India, Nepal, and Bangladesh were ranked first, third, and fourth in the prevalence of child stunting among 57 countries (12) (Madagascar was second).

All of the results here are in stark contrast to what happens in a similar analysis using data from Europe and the U.S. (11). For all of these much richer countries, heights follow the same general pattern from 1950 to 1980, rising at first and then leveling off, although the date at which the leveling off happens varies from country to country. In the lower-income northern group, the leveling off has yet to take place, although in the richest countries, such as Sweden, it was already over by 1950. Both within and between these countries, there is a close relationship between income per capita and height, both measured at the date of birth. But the pattern of human growth is in fact much better explained by variations in postneonatal mortality (PNM), particularly from respiratory infections. It seems that it was the disease environment in infancy that was the most important determinant of adult height, not the level of income per head. In all of the northern countries, a simple regression of adult height on PNM explains almost two-thirds of the pooled cross-country and time-series variation in adult height, and the significance and importance of the effect survives the introduction of country and year fixed effects. Whether the disease environment in childhood is equally important in the DHS countries, or whether income per head is more important in these much poorer countries, is one of the main questions of the present enquiry.

Given that Africans are deprived in almost all dimensions, yet are taller than less-deprived people elsewhere (although not than Europeans or Americans), it is difficult not to speculate about the importance of possible genetic differences in population heights. Africans are tall despite all of the factors that are supposed to explain height. Heights in Latin America, with mixed populations of indigenous and European (and sometimes African) descent, are heterogeneous, and Haiti, whose population is 95% black, looks much more like an African than a Latin American or Caribbean country (see Fig. 4). Women in South Asia are short and have been so for the more than century and a half for which the records extend. Today, when India's national income is twice as high as when the women here were born, child stunting, although lower, remains among the highest in the world, so that the next generation of women will be as short as their African sisters are tall.

Yet there are also good reasons for the generally prevailing view on the relative unimportance of genetic differences at the population level. There is much greater variation in height across social classes within poor countries than over the best-off groups in different countries (18). Americans of African descent (at least in large part) are as tall as Americans of Caucasian descent, and both are as tall as (most) contemporary Europeans. South and East Asian migrants to Europe and the U.S. appear to attain the same heights as the general population within a generation or two, and the children of Asian ethnic mothers in Britain are at least as well nourished as the children of white British mothers. The secular growth of heights may well be more rapid in societies where it is routinely possible for women to give birth by Caesarian section, thus enabling small women to bear tall children. As a result, better nutrition may accelerate heights much more rapidly in the U.S. or

Europe than would be the case for the same women in India. Yet even slow adaptation of heights to nutrition cannot explain why Africans are so relatively tall, unless there was some period of greater prosperity before the period considered here.

There is another reason why average heights may be insensitive to the immediate environment, at least as measured here. There may be important local variations in tastes or in the way people have adapted to general poverty and paucity of nutrients. For example, the Irish in the midnineteenth century, although poorer than the British, were taller, which has been attributed to their cheap but nutritionally complete diet of potatoes and buttermilk (19). People may manage to grow tall even at low incomes or low calorie intake. South Asians may be so short because, historically, their population could only be supported by adopting a vegetarian cereal-based diet that did not permit people to be so tall as a more balanced diet with a higher percentage of fats and animal-based foods. Similarly, in a much earlier historical episode, the mean height of hunter gatherers was reduced during the "broad-spectrum revolution," which turned diets away from the large wild animals, the hunting of which had been feasible only under lower population pressure (20). But once these restrictions are relieved, for example by economic growth in South Asia, the preferences that evolved to support the diet, most notably vegetarianism, may take many generations to change.

My results have implications for a number of strands of current research. The relationship between income and population height, which has been much relied on by economic historians, is of limited usefulness and will be downright hazardous for making comparisons across countries or continents. As in most other contexts, the link between income and health is not reliably mechanical (10). Attempts to infer African income levels or African disease burdens from African heights would fail spectacularly, much more spectacularly even than the well known but relatively minor failures in the height to income relationship in midnineteenth century Europe and America, particularly because at least some of the latter can be accounted for by an increased burden of disease. Even within countries over time, Table 1 does not suggest there is any reliable relationship between income and height. The African results also suggest the use of extreme caution in the use of skeletal remains to infer either material living standards or the disease environment of now-remote populations, although this is not to challenge the use of skeletal information to make inferences about health (21, 22). More generally, my results reinforce the view that "extreme caution should be used in making inferences from anthropometric data regarding living standards" (ref. 18, p. 141).

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