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The Mortality and Morbidity Transitions in Sub-Saharan Africa: Evidence from Adult Heights

Yoko Akachi
European University Institute

David Canning
Harvard School of Public Health

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Abstract

In most developing countries, rising levels of nutrition and improvements in public health have led to declines in infant mortality and rising adult heights. In Sub-Saharan Africa we see a different pattern. Sub-Saharan Africa has seen large reductions in infant mortality over the last fifty years, but without any increase in protein and energy intake and against a background of stagnant, or declining, adult height. Adult height is a sensitive indicator of the nutrition and morbidity prevailing during the childhood of the cohort and can be taken as a measure of health human capital. Declining infant mortality rates in Sub-Saharan Africa appear to be driven by medical interventions that reduce infant mortality, rather than by broad based improvements in nutrition and public health measures, and may not be reflective of broad based health improvements.

1. Introduction

Over the last fifty years the world has seen enormous improvements in population health in terms of falling mortality rates. These reductions in mortality rates and gains in life span occurred even in Sub-Saharan Africa, until the onset of HIV/AIDS in the recent decades, creating a large improvement in human welfare (Becker, Philipson, and Soares 2005). Historically, initial improvements in mortality have been associated with improved nutrition and public health measures such as the provision of clean water and sanitation (Cutler, Deaton, and Lleras-Muney 2006, McKeown 1983). These changes have at the same time led to reductions in childhood morbidity and improved childhood nutrition and to increases in adult stature as children exposed to the new circumstances experience physical development and become adults (Fogel and Costa 1997, Alter 2004, Crimmins and Finch 2006). We argue that this pattern continues to hold true today; in most developing countries reductions in infant mortality go hand in hand with improved nutrition, and reductions in child morbidity and rising adult heights.

In Sub-Saharan Africa, however, we find a distinctively different pattern. In Sub-Saharan Africa, while infant mortality has been falling, adult heights have been stagnating over the last 50 years. We trace this different pattern in outcomes to two sources. Firstly, in contrast to the other developing countries where nutrition, as measured by energy (calorie) or protein intake per person, has been increasing, this has not been happening in Sub-Saharan Africa. Secondly, while a reduction in a cohort's infant mortality rate is associated with an increase in that cohort's adult height in most regions, this linkage does not appear to occur in Sub-Saharan Africa.

Our explanation of this pattern is that the interventions that have produced reductions in the infant mortality rate in Sub-Saharan Africa have been different than those used in other regions of the world. We argue that, rather than broad based improvements in nutrition and public health measures to combat the spread of disease, mortality reduction in Sub-Saharan Africa has been through measures that directly reduce mortality with limited effect on morbidity.

This idea has appeared before in the literature. Huffman and Steel (1995) and Guerrant, Carneiro-Filho, and Dillingham (2003) argue that oral rehydration therapy and measles vaccination, in particular, can have large effects on infant mortality rates, while morbidity rates remain high and the physical development of children continues to be impaired. In a study that compared the survival rates between the vaccinated and unvaccinated groups for measles in Zaire, it was found that the vaccination reduced the risk of dying during the age most susceptible to the disease, but the gain in the survival probability tended to diminish afterwards, and the two survival curves approached each other later on (Kasongo 1981). In the rural part of The Gambia with a good record of infant immunizations, few children died of diseases that could have been prevented by routine immunizations, but little improvement in the stunting and wasting of children was found (Greenwood 1987). Similarly, Pinchinat et al. (2004) find that focused public health interventions such as vaccinations and malaria prevention may improve childhood survival but do not necessarily improve children's health status in Senegal. These researchers attribute the persistent high child morbidity rates, despite improvements in child mortality, to acute respiratory infections, malaria, and chronic diarrhea, which are associated with malnutrition.

We wish to investigate if these findings of lack of improvement in morbidity, even while mortality has been declining, are representative of Sub-Saharan Africa. We focus our analysis on the adult height. Physical growth during childhood and adolescence is an indicator of childhood nutrition and the disease environment (Steckel 1995, Brush, Harrison, and Waterlow 1997, Stephensen 1999). Trends in cohort height have been used by economic historians (Fogel 1993, Komlos 1993, Steckel 1995) as measures of "biological standard of living" when other indicators have not been available.

Height can also be used as an indicator of health status in modern populations (Komlos and Lauderdale 2007). Several studies have investigated the link between childhood health, nutrition, and adult height at the population level. Across developing countries, greater average protein intake is associated with greater average adult height (Jamison, Leslie, and Musgrove 2003). In addition, recent data has been used to examine the determinants of adult heights in Sub-Saharan Africa (Moradi 2002, Moradi 2006, Akachi and Canning 2007).

Adult height can in fact be thought of not only as an indicator of childhood health but also as a measure of "health capital." The same cohorts that experienced declining infant mortality rates in Sweden, France and England in the 19th century underwent gains in adult height as well as reductions in adult mortality rates (Crimmins and Finch 2006). Health capital is associated with health outcomes in adulthood due to the long-term effects of early childhood illness on cognitive and physical development and on adult health. Stunting in the first two years of life has been found to be associated significantly with poor cognitive performance in later childhood (Mendez and Adair 1999). Growth retardation in early childhood is also associated with significant functional impairment in adult life, and reduced work capacity, and thus affects economic productivity.

In microeconomic studies, the variations in adult height that are the result of childhood health and nutrition have a large impact on adult worker productivity and wages (Schultz 2002, Schultz 2005). In macroeconomic studies, up until now we have lacked worldwide data on the evolution of adult heights. As a result, macroeconomic studies tend to use mortality measures, such as life expectancy or adult survival rates, as a measure of population health capital. This, however, presupposes a one-to-one link between health capital as determined by height and health capital as determined by mortality measures. Although Weil (2007) argues that in the long run such a link holds in many countries, our analysis suggests this link may have broken down in Sub-Saharan Africa. It may be dangerous to take the improvements in infant mortality in Africa as indicative of broad based improvements in population health.

2. Data

Most of height data we use come from Demographic and Health Surveys, though we also use Family Life Surveys (FLS) for Mexico and Indonesia, and World Bank Living Standard Measurement Surveys (LSMS) for Albania. All available Demographic and Health Surveys that include height as a variable were employed in this analysis (with the exception of Egypt[1]). Height in Demographic and Health Surveys is measured by the interviewer, using a headboard. The typical Demographic and Health Surveys dataset contains the heights of women from age 15 to 49. Though the probability of being sampled is usually unequal for different observations, these are nationally representative samples. We use the sampling weights provided to construct an average height for each cohort by birth year, and we extract the heights of women from only age 20 and above on the grounds that at age 20, physical developments have ceased.

One complication is that in earlier surveys, only the height of mothers with children under 5 was measured (in later Demographic and Health Surveys, the height of all women 15 to 49 was measured). This creates a sample selection problem since mothers are not a random sample. For example, assuming that higher socioeconomic status is associated with fewer children, if height is

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[1] In other countries height data from different waves of the DHS survey gave very similar results for each birth cohort's height whereas the Egyptian data gives vary different measures of a cohort's height in different surveys.

positively linked to socioeconomic status then the average height of mothers may be lower. In our check on data consistency, we examined the average height of each cohort as measured in different DHS surveys and found them to be remarkably similar, independently of whether the data were for all women or just mothers. These findings agree with those of Moradi (2006), who argues that there is little selection bias due to this issue in developing countries because the vast majority of adult women have children.

While we have large samples from FLS and LSMS, these are often not nationally representative samples and are available only for a smal number of countries. The only countries for which we use the FLS are Mexico and Indonesia. The only country where we use the LSMS is Albania. In these cases the FLS and LSMS surveys are nationally representative (or close to being so).

We construct average height for each cohort by year of birth from each survey. For each country with multiple DHS surveys, cohort heights by birth years were graphed to check for consistency when the same cohort is included in different surveys (Figure 1 gives an exampel graph). In most cases the results for different surveys were very similar. The only country in which we found considerable variation was Egypt. Egypt has three DHS surveys, one of which, the 2003 survey consistently and considerably differs from the other two in 1995 and 2000. Therefore the surveys from Egypt were discarded.

In order to construct figures for average cohort height we average over available DHS surveys for each country when multiple of them are available (The same was done for the two FLS Indonesia surveys). This gives larger sample sizes except at the beginning and end of the series where often only data from one survey is available. Example for the three DHS surveys of Bolivia is shown in Figure 1. The newer DHS survey with larger sample size has less volatility compared to the earlier DHS surveys. Larger sample size reduces the measurement error in the cohort average and result in noticeably lower volatility in average heights

In principle, different DHS surveys should give comparable results for the same cohort (same birth year) in a country since the samples are nationally representative, however, the survey design is cased on clustered random sampling, and sampling variation depends on the number of clusters as well as the number of observations. We find that while surveys usually agree quite well there is substantial measurement error in our estimate of cohort average height due to sampling. The number of observations for each cohort from a survey is used to weight in taking the averages for a particular cohort across different surveys.

We compare heights with indicators for health and nutrition. Data on the percentage of children who are stunted also come from Demographic and Health Surveys. We use infant mortality rate from the World Bank's World Development Indicators (2005), with data going back to 1960, as a health measure. For the infant mortality rate we interpolated over gaps of one to two years to derive an annual time series.

For nutrition we use daily average consumption of calories and protein from the World Food Organization (2006) FAOSTAT database, with data going back to 1961. The Food and Agriculture Organization (FAO) food balance sheets calculate the consumption of each foodstuff. Consumption of foodstuffs is calculated from two sources: national food supplies given by production plus imports, minus exports and wastage, and data on food consumption from household surveys. Jacobs and Sumner (2002), discuss the construction of the food balance sheets, problems in constructing the data, and their appropriate use. Calories and Protein consumed per capita are calculated from national consumption of each foodstuff using nutritional tables of calorie and protein content, and dividing by the population.

Akachi and Canning paper (2007) contains a more detailed discussion of these data sets.

3. Results

We begin by investigating the link between physical development, infant mortality, and nutrition, looking at how these change over time in developing countries. Table 1 shows the time trends for infant mortality rates, protein, and calorie intake for countries in Sub-Saharan Africa, from 1961 to 1985, matched with the trends in adult height for cohorts born during that period. In every country in the region except Rwanda, we see statistically significant declines in the infant mortality rate. In terms of protein and calorie intake, the picture in Sub-Saharan Africa is much more mixed: as many countries have seen declines in nutritional intake as have seen increases. Finally, adult heights have risen significantly in only two countries, Kenya and Senegal, whereas three countries, Chad, Ethiopia and Rwanda, have seen heights decrease.

We can compare these trends with those in developing countries outside Sub-Saharan Africa over the same time period, as shown in Table 2. Infant mortality rates fell significantly in every country outside Sub-Saharan Africa. Nutrition in the form of either calorie or protein intake increased significantly in every country except Bangladesh, Nicaragua, and Peru. Adult heights also increased significantly in every country except Bangladesh, where they stagnated.

These national trends are summarized in Table 3 where we report regional time trends represent the average annual change in the variable in that region (averaged over the country averages). In terms of infant mortality, we find very similar rates of decline in Sub-Saharan Africa and developing countries in other regions: a decrease of about 2.1 versus 2.4 infant deaths per thousand live births each year. On the other hand, while both protein and calorie consumptions have been increasing significantly elsewhere, within Sub-Saharan Africa protein and calorie consumption remained virtually unchanged over the whole period. The trends in height are also quite distinct. In Sub-Saharan Africa, heights overall have been decreasing; the cohort born in 1985 is about 0.5 centimeters shorter that the cohort born in 1961. In contrast, in the rest of the developing world, the height of adult women has risen by approximately 1.6 centimeters on average during this twenty-four year period.

Weil (2007) argues that we can think of health as a single, uni-dimensional, concept and that in the long run both population heights and mortality rates are responding to a single impulse. In this case, heights and mortality rates should tell the same story about the underlying health of the population, giving a stable relationship between heights and mortality rates. Our data suggests that this is not true for Sub-Saharan Africa, since average adult height is declining while infant mortality rates are falling. We think both adult height and infant mortality rates respond to nutritional intakes and the underlying disease burden when young. This means that infant mortality rates and adult heights will be linked. This allows us to study two possible reasons why adult heights have not increased in Sub-Saharan Africa. The first possibility is that it is due to the lack of growth in nutritional intake. The second is that the relationship between disease burden, mortality, and adult height is different in Sub-Saharan Africa than in other regions of the world.

Many studies take anthropometric measures as indicators of nutritional status; we prefer to measure nutritional status more directly by protein and calorie consumption. We assume that adult heights depend on nutrition intakes when young and the morbidity experienced in childhood due to the disease environment.[2] More formally, let us suppose average height, h, in country i at time of

[2] The net nutrition approach would also include the effect of labor and other physical activity in childhood that consumes energy and reduces the

the cohort born at time t depends on nutrition, n, and the disease burden, d, when the cohort is young according to the equation

$$h_{it} = f_i + \alpha n_{it} + \beta d_{it} + \varepsilon_{it} \qquad (1)$$

Where f_i represents a country specific fixed effect and ε_{it} is an error term.

Baten (2000) point out that infant mortality rates depend on nutrition as well as the disease environment. Formally, we assume that the infant mortality rate varies with nutrition and the disease burden according to

$$m_{it} = \sigma_t + \delta n_{it} + \gamma d_{it} \qquad (2)$$

where the time dummies σ_t reflect worldwide technological progress that may improve mortality outcomes, even with the same nutrition level of disease environment.

The disease burden is not observed in our dataset. However, combining these two equations we can derive a relationship between adult height and nutrition and infant mortality when young.

$$h_{it} = f_i - \frac{\beta}{\gamma}\sigma_t + (\alpha - \frac{\delta}{\gamma})n_{it} + \frac{\beta}{\gamma}m_{it} + \varepsilon_{it} \qquad (3)$$

This is the relationship we estimate. Note that technical progress in medicine that reduces infant mortality at a given level of nutrition and disease burden will show up as a downward time

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remaining energy balance available for physical growth.

trend in heights (controlling for nutrition and infant mortality).

To investigate this relationship, we run a regression showing how cohort adult heights vary with infant mortality rates and average nutritional intake when the cohort was young. We do not assume a causal link running from infant mortality rates to adult heights. Rather, as the equations above make clear, both should move together because they both reflect underlying changes in nutrition and the disease burden.

In our regression we include country-specific fixed effects. If we simply consider average heights across countries, there is little evidence that better fed and healthier populations are taller. Indeed the opposite is true; Africa has the least healthy and most malnourished population, but it has the tallest adults (Deaton 2007). However, Akachi and Canning (2007) show that, when controlling for country-specific fixed effects, a higher level of nutritional intake and a lower infant mortality rate go hand in hand with a cohort having greater height. The country fixed effect may reflect genetic or environmental sources of variation in height across countries (Ruff 2002).

We also include a worldwide time trend to allow for technical progress that might change the relationship between the disease environment and infant mortality (for example, the development and use of oral rehydration therapy (da Cunha Ferreira and Cash 1990)). We estimate using weighted least squares, weighting each observation by the number of observations that go into our calculation of the average cohort height for that birth year, since larger samples give more accurate measures of the cohort's average height.

The regression result of the full model is shown in Table 4. This estimates a model where the infant mortality rate, calorie and protein consumption when young determines adult height. We include these influences at birth and ages 5, 10 and 15, since exposures at different times during the process of physical growth can affect final height. The effects are estimated separately for Sub-Saharan Africa and the other developing countries. Table 5 reports a test of the joint hypothesis that infant mortality at any age during childhood has no effect adult height (all coefficients on infant mortality in the regression are zero). We reject the null of no effect. A test that protein consumption does not matter was likewise rejected. However, we fail to reject the hypothesis that calorie consumption has no effect (that is, that all coefficients on calorie variables are zero). We therefore remove the calorie variables from the regression.

The regression was then re-estimated without the calorie variables. Table 6 reports the results of tests for the age at which influences on adult height occur. We reject both the hypotheses that the environment at birth, and the environment at age five have no effect. However, we cannot reject the hypotheses that factors measured at age ten and fifteen have no effect. Since these tests suggest that calorie consumption, and variables measured after age 5, do not have a significant effect on adult heights, we remove them from our analysis.

Table 7 reports a regression on the relationship between average cohort height, the infant mortality rate, and average protein intake in the country in the year of the cohort's birth and at age five. In Sub-Saharan Africa, we find that lower infant mortality is associated with increased adult height; however, the individual coefficients on infant mortality at birth and age five are not statistically significant. Outside Sub-Saharan Africa, we find a much stronger link between low infant mortality rates at birth and adult height, both in terms of the size of the coefficients and their statistical significance. In both areas, we find average protein intake in childhood to be significantly associated with height in adulthood. In Sub-Saharan Africa, protein intake at birth seems most relevant, whereas in the rest of the developing world, protein intake at age five appears to be more important.

In Table 8 we report the sum of the estimated effects of each variable reported in Table 7, adding the effects at birth and at age five. This shows how much we would expect adult height to increase if protein consumption rose both at birth, and at age five, by the same amount. For protein intake, the cumulative effects are roughly similar in Sub-Saharan Africa and the rest of the developing world; the difference is not statistically significant. We estimate that an additional 100 grams of protein consumption pay day, per person, throughout childhood is associated with an increase in height of approximately 2.6 centimeters in Sub-Saharan Africa and an increase of approximately 1.9 centimeters in the rest of the developing world.

The relationship between infant mortality decline and adult height in Sub-Saharan Africa appears to be different from that found in the rest of the developing world. A reduction in the infant mortality rate by 100 per thousand births is associated with an increase in adult height of approximately 1.5 centimeters in Sub-Saharan Africa and approximately 5 centimeters in other developing countries. This difference is statistically significant. The finding that the coefficient on infant mortality, β / γ in equation (3), is different in Sub-Saharan Africa and other developing countries means that either β, the effect of the disease environment on adult height, or γ, the effect of the disease environment on the infant mortality rate, differs across regions.

These results suggest that the stagnation in adult height in Sub-Saharan Africa has two causes. The first is that while protein intake in childhood is significantly related to gains in adult height, there was little or no improvement in average food consumption in Africa between 1960 and 1985. The second is that in other regions of the world, reductions in infant mortality reflect a falling disease burden, and are associated with lower childhood morbidity, the improved physical development of children, and greater stature in adulthood. In Sub-Saharan Africa, there have been large improvements in infant mortality rates, but these have translated into only small improvements in adult height. Therefore, reductions in infant mortality in Sub-Saharan Africa do not seem to have been strongly associated with a falling burden of disease and lower childhood morbidity; a different pattern of health improvements, focused on mortality rather than morbidity is emerging in Africa.

Recent Trends

Data on adult heights are only available for cohorts born before 1985 in our data. For cohorts born after 1985, we do not yet know what their adult height will be, but we can observe their early physical development. Table 9 shows changes in the percentage of children under five who are stunted (low height for age) as well as the time trends in infant mortality rates, calorie intake and protein consumption during the period 1985 – 2002. We find that the prevalence of childhood stunting is continuing unabated in Sub-Saharan Africa, while it is falling significantly in the rest of the developing world. This suggests that the stagnation in adult height in Sub-Saharan Africa will continue. The rate of decline in infant mortality rates, while remaining rapid in the rest of the developing world, has slowed in sub-Saharan Africa, reflecting HIV/AIDS mortality among children. The only bright spot is the significant increase in average calorie consumption in Africa, though this does not seem to be paralleled by any rise in protein intake. Pelletier and Frongillo (2003) find that, whereas around the world reductions in infant mortality rates tend to go hand in hand with reductions in the percentage of children stunted, in Sub-Saharan Africa this link breaks down: reductions in infant mortality do not lead to a lower percentage of stunted children. Harttgen and Misselhorn (2006) find a different relationship between infant mortality rates and children's physical development in Asia and Africa. These results are consistent with our finding for adult heights.

4. Conclusion

In most of the developing world, and in the historical record of developed countries, there has been a consistent picture of advances in infant mortality rates, improvements in nutrition, and increases in adult height, with all of these developments proceeding together. In Sub-Saharan Africa, however, we are seeing a very different pattern unfold. While there have been large reductions in infant mortality, nutrition intake and adult stature have not improved.

The health transition in terms of mortality-morbidity taking place in Sub-Saharan Africa appears to be driven by medical interventions that reduce mortality, rather than by nutrition improvements and broad based reductions in exposure to infectious diseases that would reduce morbidity. This has several implications. It reinforces the view that population health is multidimensional. Movements in mortality measures, such as infant mortality rates and life expectancy, may give a limited picture of how broader population health is changing. It appears that adult cohort height can be used, with caution, as an independent measure of population health in addition to other conventional health indicators such as infant mortality rate. Health is multi-dimensional, and each indicator of health could be measuring varying aspects of health.

This has implications for studies of the effect of health on worker productivity. In macroeconomic studies of the effect of health on economic growth (Bloom, Canning, and Sevilla 2004) life expectancy or adult mortality rates are often used as measures of population health, assuming that these measures are closely linked to adult height (Shastry and Weil 2003) as used in microeconomic studies (Schultz 2002). This assumption may be unwarranted. This also questions the convention of focusing on the use of mortality rate as an indicator of population health in international efforts, notably in Millennium Development Goals (MDG), where focal point has been on reducing the mortality rate and the nutrition has been seen as the "forgotten" MDG.[3]

Finally, the continuing child morbidity and lack of physical development may be highly significant for the future of the aging population in Africa. While the African population is aging (National Research Council 2006), there is strong evidence that the health of adults and the elderly is affected by their childhood health and nutritional status (Fogel and Costa 1997, Catalano and Bruckner 2006, Brush, Harrison, and Waterlow 1997, Blackwell, Hayward, and Crimmins 2001). This suggests that the lack of nutrition and high levels of morbidity among children in Sub-Saharan Africa may be producing unhealthy adults and a growing future health burden.

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[3] World Bank, 2008:
http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:21627646~pagePK:34370~piPK:34424~theSitePK:4607,00.html

Table 1

Time Trends in Adult Height, Infant Mortality, and Nutrition
Sub-Saharan Africa, 1961- 1985

Country	Adult Height (cm)	Infant Mortality Rate (deaths per 1,000 live birth)	Calories (calories per capita per day)	Protein (grams per capita per day)
Benin	-0.001	-2.310**	4.466	0.119
	(0.014)	(0.037)	(2.486)	(0.068)
Burkina Faso	0.007	-2.110**	0.643	-0.135
	(0.007)	(0.023)	(2.904)	(0.088)
Cameroon	0.010	-2.249**	8.697**	0.008
	(0.012)	(0.014)	(2.809)	(0.096)
Central Africa	0.069	-2.905**	-2.321	0.180**
	(0.042)	(0.098)	(4.265)	(0.026)
Chad	-0.034*	-3.033**	-36.048**	-1.360**
	(0.016)	(0.140)	(2.845)	(0.87)
Comoros	-0.054	-3.710**	-8.055**	0.371**
	(0.042)	(0.040)	(1.361)	(0.026)
Cote d'Ivoire	0.024	-3.806**	22.622**	0.403**
	(0.023)	(0.069)	(2.998)	(0.074)
Ethiopia	-0.068**	-1.784**	-3.795	-0.391**
	(0.017)	(0.018)	(3.273)	(0.109)
Gabon	0.016	-4.365**	27.524**	1.076**
	(0.032)	(0.112)	(1.725)	(0.069)
Ghana	0.018	-1.763**	-18.089**	-0.129
	(0.015)	(0.026)	(5.527)	(0.148)
Guinea	-0.021	-2.149**	-6.328*	-0.051
	(0.023)	(0.037)	(2.119)	(0.042)
Kenya	0.050**	-2.258**	-0.493	-0.319**
	(0.010)	(0.046)	(2.248)	(0.086)
Madagascar	-0.024	-0.300**	0.118	-0.234**
	(0.017)	(0.0001)	(1.565)	(0.052)

Malawi	-0.005	-2.388**	3.552	-0.018
	(0.009)	(0.063)	(3.536)	(0.122)
Mali	0.015	-5.431**	-13.782**	-0.404**
	(0.015)	(0.172)	(3.376)	(0.090)
Mozambique	-0.011	-1.788**	-2.912*	-0.155**
	(0.020)	(0.060)	(1.284)	(0.036)
Niger	-0.015	-0.817**	19.282**	0.577**
	(0.001)	(0.048)	(2.399)	(0.107)
Nigeria	-0.010	-0.300**	-12.487**	-0.280**
	(0.017)	(0.0001)	(2.781)	(0.083)
Rwanda	-0.023	0.125	18.585**	0.230*
	(0.012)	(0.071)	(2.419)	(0.091)
Senegal	0.074**	-2.658**	-6.115	0.012
	(0.025)	(0.134)	(3.287)	(0.097)
Tanzania	0.005	-1.817**	28.325**	0.783**
	(0.021)	(0.039)	(3.361)	(0.081)
Togo	-0.008	-2.578**	-9.458**	-0.014
	(0.025)	(0.031)	(3.237)	(0.081)
Uganda	-0.008	-1.019**	-5.479	-0.124
	(0.018)	(0.093)	(2.781)	(0.133)
Zambia	0.013	-1.322**	-0.272	-0.334**
	(0.013)	(0.092)	(2.781)	(0.098)
Zimbabwe	-0.009	-1.474**	1.673	-0.295**
	(0.023)	(0.027)	(2.107)	(0.084)

Coefficient of the time trend by country.
Coefficients represent per annum change, standard errors in parentheses, significance level indicated as *(5%), **(1%).
Height trends estimated with weighted least squares; weighted by the number of individuals used to calculate the cohort average height.

Table 2
Time Trends in Adult Height, Infant Mortality, and Nutrition
Non Sub-Saharan African Developing Countries, 1961- 1985

Country	Adult Height (cm)	Infant Mortality Rate (deaths per 1,000 live birth)	Calories (calories per capita per day)	Protein (grams per capita per day)
Albania	0.179*	-2.058**	26.641**	0.801
	(0.050)	(0.096)	(2.356)	(0.070)
Bangladesh	0.007	-1.366**	-5.519*	-0.0007
	(0.006)	(0.094)	(2.119)	(0.037)
Bolivia	0.071**	-2.262**	15.255**	0.357**
	(0.005)	(0.106)	(1.981)	(0.048)
Brazil	0.062**	-2.264**	18.466**	0.217**
	(0.017)	(0.019)	(1.384)	(0.039)
Colombia	0.096**	-2.139**	16.721**	0.152**
	(0.004)	(0.070)	(2.334)	(0.004)
Dominican Republic	0.068**	-1.656**	23.076**	0.434**
	(0.001)	(0.040)	(1.055)	(0.030)
Guatemala	0.040	-2.125**	13.117**	0.091
	(0.024)	(0.046)	(2.068)	(0.046)
Haiti	0.044	-1.939**	3.085**	0.185**
	(0.020)	(0.031)	(0.905)	(0.023)
India	0.027**	-1.753**	6.021*	0.054
	(0.009)	(0.038)	(2.245)	(0.058)
Indonesia	0.081**	-2.396**	28.626**	0.753**
	(0.010)	(0.014)	(2.028)	(0.047)
Mexico	0.121**	-1.968**	37.350**	0.950**
	(0.011)	(0.033)	(1.846)	(0.092)
Morocco	0.085**	-1.899**	30.844**	0.734**
	(0.008)	(0.063)	(1.126)	(0.065)
Nepal	0.046**	-3.747**	7.908**	0.253**
	(0.010)	(0.071)	(1.557)	(0.036)
Nicaragua	0.028**	-2.464**	0.752	-0.331**

	(0.005)	(0.062)	(1.619)	(0.102)
Peru	0.086**	-2.991**	-2.154	-0.079
	(0.006)	(0.067)	(2.329)	(0.061)
Turkey	0.074**	-3.428**	19.735**	0.383**
	(0.019)	(0.156)	(1.348)	(0.049)

Coefficient of the time trend by country.
Coefficients represent per annum change, standard errors in parentheses, significance level indicated as *(5%), **(1%).
Height trends estimated with weighted least squares; weighted by the number of individuals used to calculate the cohort average height.

Table 3

Regional Time Trends in Adult Height, Infant Mortality, and Nutrition, 1961- 1985

Region	Adult Height (cm)	Infant Mortality Rate (deaths per 1,000 live birth)	Calories (calories per capita per day)	Protein (grams per capita per day)
Sub-Saharan Africa	-0.021** (0.003)	-2.120** (0.052)	0.394 (0.820)	-0.019 (0.025)
Other Developing Countries	0.066** (0.003)	-2.359** (0 037)	16.488** (0.795)	0.333** (0.022)

Coefficient reported on common regional time trend with country fixed effects.
Coefficients represent per annum change, standard errors in parentheses, significance level indicated as *(5%), **(1%).
Height trends estimated with weighted least squares; weighted by the number of individuals used to calculate the cohort average height.

Table 4 Determinants of Cohort Height: Full Model

Dependent Variables: Cohort Average Height

	Sub-Saharan Africa	Other Developing Countries
Infant mortality rate at birth/100	-1.337	-3.230**
	(1.114)	(0.872)
Infant mortality rate at age five/100	-0.727	-1.301
	(1.811)	(1.569)
Infant mortality rate at age ten/100	0.927	-0.885
	(1.495)	(1.827)
Infant mortality rate at age fifteen/100	-0.237	0.677
	(0.886)	(1.098)
Protein consumption at birth/100	4.312*	-3.227*
	(1.678)	(1.637)
Protein consumption at age five/100	-1.556	0.878
	(1.588)	(1.586)
Protein consumption at age ten/100	2.327	-0.458
	(1.545)	(1.621)
Protein consumption at age fifteen/100	0.353	2.740
	(1.417)	(1.588)
Calories consumption at birth/100	-0.021	0.089
	(0.056)	(0.051)
Calories consumption at age five/100	0.018	0.030
	(0.052)	(0.052)
Calories consumption at age ten/100	-0.035	0.008
	(0.046)	(0.053)
Calories consumption at age fifteen/100	0.022	-0.083
	(0.042)	(0.052)
Worldwide time trend	-0.066** (0.010)	
Constant	165.408**(1.305)	
R^2	0.983	
N	754	

Data for 41 countries. Country fixed effects and worldwide time trend included. Coefficients estimates with standard errors in parentheses. Significance level indicated as *(5%), **(1%). Estimation with weighted least squares; weighted by the number of individuals used to calculate the cohort average height.

Table 5

Test of Coefficients for Infant Mortality Rate, Protein, and Calories

	Infant Mortality Rate	Protein	Calories
F test	F(8,688) = 18.55	F(8,688) = 2.06	F(8, 688) = 1.20
p-value	0.0000	0.038	0.293
Ho	Reject	Reject	Fail to reject

Table 6

Test of Coefficients for Ages

	Birth	Age five	Age ten	Age fifteen
F test	F(4,696) = 9.58	F(4,696) = 2.65	F(4, 696) = 1.16	F(4, 696) = 1.49
p-value	0.0000	0.032	0.328	0.204
Ho	Reject	Reject	Fail to reject	Fail to reject

Table 7 Determinants of Cohort Height: Final Model

Dependent Variables: Cohort Average Height

	Sub-Saharan Africa	Other Developing Countries
Infant mortality rate at birth/100	-1.369	-3.343**
	(0.904)	((0.743)
Infant mortality rate at age five/100	-0.165	-1.648*
	(0.980)	(0.766)
Protein consumption at birth/100	3.076**	0.833
	(0.715)	(0.912)
Protein consumption at age five/100	-0.475	2.704**
	(0.706)	(0.796)
Worldwide time trend	-0.068**	
	(0.009)	
Constant	165.271**	
	(1.058)	
R^2	0.983	
N	754	

Data for 41 countries.
Country fixed effects and worldwide time trend included.
Coefficients estimates with standard errors in parentheses. Significance level indicated as *(5%), **(1%).
Estimation with weighted least squares; weighted by the number of individuals used to calculate the cohort average height.

Table 8
Long Run Relationship between Infant Mortality, Nutrition and Adult Height in Developing Countries

	Sub-Saharan Africa	Other Developing Countries	Difference
Infant mortality rate (deaths per 1,000 live birth)	-1.535** (0.449)	-4.992** (0.395)	3.457** (0 .332)
Protein consumption (grams per capita per day)	2.600** (0.895)	1.870 (0.843)	0.730 (1.238)

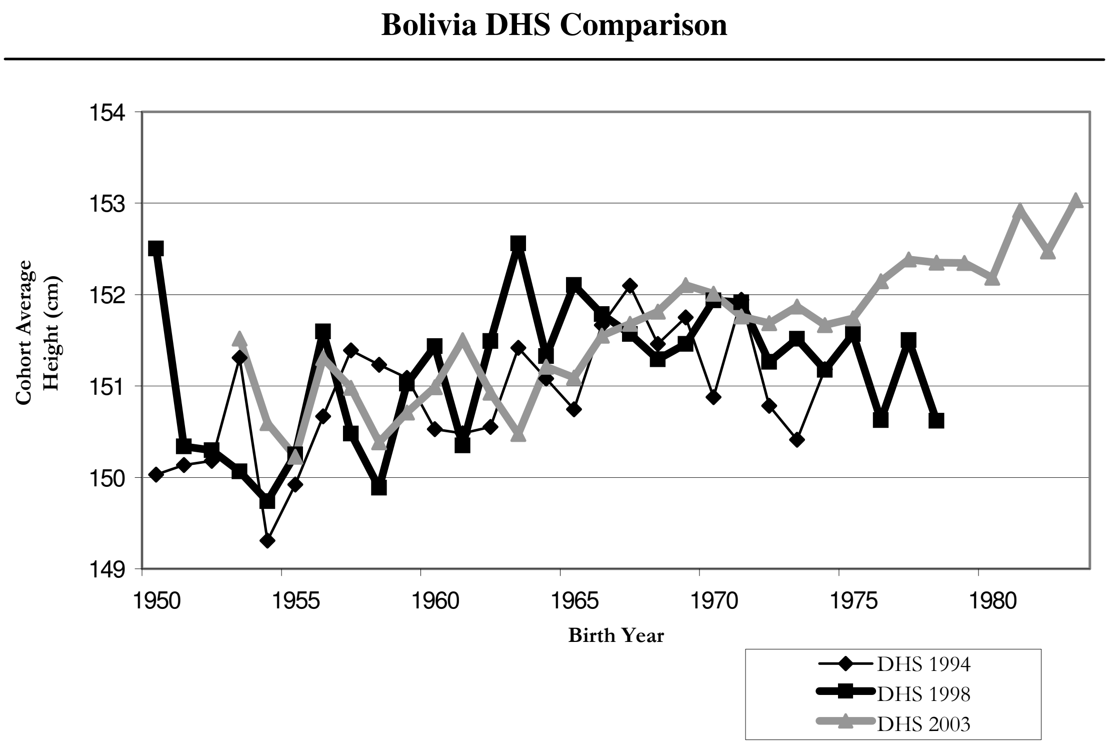
Calculated by summing the age specific coefficients in Table 7.
Standard errors in parentheses, significance level indicated as *(5%), ** (1%).

Table 9
Regional Time Trends in Stunting, Infant Mortality, and Nutrition, 1985- 2002

Region	Percent Children Stunted	Infant Mortality Rate (deaths per 1,000 live birth)	Calories (calories per capita per day)	Protein (grams per capita per day)
Sub-Saharan	-0.054	-0.669*	7.740**	0.072
Africa	(0.123)	(0.313)	(2.393)	(0.082)
Non Sub-Saharan	-0.819**	-2.230**	7.006	0.246
Africa	(0.118)	(0.313)	(5.397)	(0.182)

Coefficient reported on common regional time trend with country fixed effects.
Coefficients represent per annum change, standard errors in parentheses, significance level indicated as *(5%), ** (1%).

Figure 1



Bolivia DHS Comparison
154
153
152
151
150
149
Cohort Average Height (cm)
1950
1955
1960
1965
1970
1975
1980
Birth Year
DHS 1994
DHS 1998
DHS 2003

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