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Trends in female adult height and GDP per capita in sub-Saharan Africa

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Abstract

The paper presents the correlation between trends in female adult height and in GDP per capita in 33 countries of sub-Saharan Africa. Anthropometric data are drawn from DHS surveys, which provide mean height by cohort for women born between 1940 and 1990. Income data are drawn from the database gathered by Angus Maddison, from 1950 to 2008. The correlation between both trends was found very high (0.97). When GDP increases, the height of adult women increases, and when GDP declines the same happens to women's height. This correlation is analyzed by four major population groups: West and Central Africa, Sahelian countries, Eastern Africa and Southern Africa, and further analyzed by period of changes in GDP at country level. The pattern found in Africa is compared with similar historical situations of declining adult height in Europe.

Key words: Anthropometry; Secular trends in height; Women health; Economic growth; Economic development; Genetic factors; sub-Saharan Africa.

Introduction

Adult height is determined by health and nutrition before age 20, and has a strong genetic component. [Tanner 1981; Eveleth & Tanner 1990] Three periods of the life cycle are more important than others for determining adult height: the intra-uterine period, the early childhood (age 0-2 years), and adolescence (age 10-18 years). In periods when health and nutrition improve, adult height increases, whereas in difficult times when health and nutrition deteriorate adult height might be reduced, depending on the severity of the crisis. Increasing adult height usually correlates with increasing height of children and of adolescents, and with earlier sexual maturation (earlier age at puberty). [Danubio & Sanna 2008] Numerous studies have documented the so-called "secular trend" in adult height in developed countries, that is the long term increase in male and female adult height, in Europe, the United States, Russia, Japan, and many other countries with increasing income per capita. [Floud et al. 2011; Chamla 1986; Malina 2004; Cole 2003; Onland-Moret et al. 2005; Baten 2006; Meredith 1976; Garcia & Quintana-Domeque 2007] For instance, in France, male height increased from about 163 cm for men born in 1775, to 166 cm for those born in 1900, and 175 cm for those born in 1975. The increase was slower in the 19th century (0.3 cm per decade) and much faster in the 20th century (about 1.1 cm per decade). Female height also increased, but more slowly than for males in the 20th century, from about 160 cm in 1910 to 164 cm in 1973 (about 0.6 per decade). [Floud et al. 2011, Singh-Manoux et al. 2010] Increases in adult height correlate with increases in income per capita and corresponding improving living standards. [Steckel 1995] In France, average economic growth was about 1.2% per year in the 19th century (1800-1899), and 2.0% per year in the 20th century (1900-1975). [Maddison 2010]

Periods of difficult times may be associated with decreasing adult height, especially for cohorts who were adolescent at time of serious food shortage. For instance, in France, cohorts born in 1930 who were adolescent during the difficult years of the war (1942-1945) were shorter than cohorts born before or after (deficit of -0.9 cm for men and -0.6 cm for women). [Singh-Manoux, 2010] This period was associated with food restriction and with a major decline in income per capita (-49%). A similar change was found during the civil war in Spain. Cohorts of army recruits who were adolescent in 1933-1936, were also shorter (-0.7 cm) than those born before and after. [Maria-Dolores & Martinez-Carion, 2010] The Spanish civil war also induced a major decline in income per capita (-30%). [Maddison 2010]

The effect of genetic factors is complex and not fully understood. [McEnvoy & Vissher 2009] For instance, in Europe, major differences could be found at similar level of

income and life expectancy. Men born in 1975 averaged 183 cm in Denmark and 179 cm in Sweden, but only 175 cm in France and 177 in England. Differences were smaller for women, ranging from 168 cm in Denmark and 167 in Sweden, to 164 cm in France and 165 cm in England. Genetic factors could account for differences of 3 or 4 cm for women in Europe, at similar level of income and development. [Floud et al. 2011; Garcia & Quintana-Domeque 2007]

The aim of this paper is to relate trends in income per capita since 1950 with secular trends in female adult height in sub-Saharan Africa, after controlling for genetic factors. Sub-Saharan Africa went through major changes in income per capita over the past 60 years, with ups and downs, which are expected to have an impact on adult height. We focus here on female adult height because these are the only data available. Genetic factors are also important in Africa, visible in variations in body shape. Some ethnic groups have typically long legs whereas others have shorter legs given trunk height. [Meredith 1966] African countries also differ markedly in level of development and in income per capita. Other studies have already addressed this issue of changing adult height in Africa, however without taking into account cohort and period effects and while ignoring genetic factors. [Akachi & Canning 2007 and 2010; Moradi 2010; Cogneau & Rouanet 2009]

Data and methods

Data on women's height were drawn from Demographic and Health Surveys (DHS). Since the second round of DHS starting in 1991, the weight and height of adult women interviewed in DHS samples was recorded in most, although not all surveys. The list of surveys available and used for this study is provided in annex and displayed on the map. [Annex 1; Map 1] Average height of adult women was calculated by cohort (year of birth). For women aged 15-19 a small correction factor was applied to take into account increasing height up to age 20. Details of the procedure can be found elsewhere [Garenne, 2011a]

Data on income per capita were taken from the database constructed by Angus Maddison and colleagues [Maddison, 2010]. These data provide estimates of Gross Domestic Product in Purchasing Power Parity (GDP-PPP) per capita in constant US dollar (USD). They are available for all 33 countries selected, and for the whole 1950-2008 period.

To account for the large variations in genetic endowment and in level of development found in Africa, four population groups were considered. These groups were identified by

cross-tabulating mean height with mean body mass index (BMI): (1) “Central”: a group of countries located on the West Africa coast, in Central Africa and two countries in East Africa (Uganda and Kenya): this group has an average height and an average BMI. (2) “Sahelian”: a group of countries located in the Sahelian band going from Senegal to Sudan, where women are tall and slim (higher height than average, low BMI). (3) “Eastern”: a group of countries located in Eastern Africa, including Madagascar, where women are short and slim (lower height than average, low BMI). These countries are poorer than average, and have more childhood nutrition (more stunting). (4) “Southern”: a group of countries located in Southern Africa, where women have an average height, but have higher BMI. These are countries which are more affluent than average, where nutritional problems are different, with less stunting and more resources.

Beyond genetic factors and factors associated with level of development, two types of controls were added at household level: urban residence and wealth, mainly because patterns of feeding are different in urban and rural areas and by household wealth. A wealth index was calculated from household characteristics, as the sum of 14 dummy variables indicating the presence of modern goods and amenities in the household. This absolute wealth index has been described in more details elsewhere. [Garenne 2011a; Garenne & Hohmann 2003; Hohmann and Garenne 2011].

Data analysis was first conducted at country level. Merging countries was done by applying a standard set of weight, proportional to country’s populations in year 2000 provided by the United Nations Population Division (UNPD, 2007).

Results

1) Overall trends

For the whole set of selected countries, the average income per capita fluctuated markedly from 1950 to 2008, with three major periods: a first period of increasing trends, from 823 USD in 1950 to 1303 USD in 1974, implying an average growth rate of +1.9% per year; a second period of recession, up to 1994 where the average income was 1038 USD, implying a negative growth rate of -1.1%; a third period of economic growth up to 2008, the last point available. This third period is of little importance for our study, since children who

grew up during this period were not yet adults when the fifth round of DHS surveys was conducted, so we do not know yet what will be their adult height. [Table 1]

Trends in female adult height followed closely trends in income, with a high correlation coefficient= 0.97. [Figure 1] Women who were born between 1940 and 1966, who were adolescent during the favorable years (1950-1974), had increasing height, from 157.3 cm to 158.7 cm. The magnitude of increasing height (+0.5 cm per decade) is consistent with similar increases in Europe, although not as fast as increases seen after 1950. On the contrary, women who were born between 1967 and 1990 had decreasing height, following the recession during the years when they were adolescent. The losses in adult height endured during the difficult years were almost as fast as the increases during the favorable years, so that women born in 1990 were hardly taller than their grand mothers born in 1940. This long term decline in adult height, lasting almost a generation, is unique in the 20th century, and no other large population group seems to have suffered such an impressive downturn.

2) Trends by population groups

Trends in both income per capita and in adult height differed markedly by population groups defined above. The “Central” group, which had the largest population, and included Nigeria the largest country, followed the average pattern, as anticipated because of its large demographic weight. The “Sahelian” group behaved differently: firstly the economic recession was much milder, with a small decline of −0.1% per year, compared with −1.4% per year in the “Central” group. Secondly, and most likely for genetic reasons, this group was much taller than average, despite being poorer. As a result, the impact of the recession on adult height (−0.7 cm) was much smaller than in the previous group (−1.7 cm). The “Eastern” group cumulated all difficulties, with lower income per capita, more malnutrition in childhood, and lower adult height. The recession was as marked as in the “Central” group (−1.4% per year), but the impact was lower (−0.6 cm), and similar to that found in the “Sahelian” group. The last group of “Southern” countries behaved differently since it did not show any declining height, despite an economic recession. The reason seems to be that the recession occurred at a much higher level of income, where under-nutrition is much less prevalent, as seen by the much higher BMI, so that a minor decline in income did not translate into declining heights. In conclusion, the impact of the economic recession varied much by country and large areas, and depended upon both the level of development and the genetic endowment.

3) Multivariate analysis

The aggregate analysis presented above was confirmed by multivariate analysis at household level. Of course, no data was available on income at household level, so that only time trends are considered here. Controls were urban residence and wealth. Results of the regressions on time, urban residence and wealth confirmed the major changes in height trends around year of birth 1966-1967. [Table 2] The level of statistical significance was not questionable, with P-values of changes in slope below 10^{-10}. Compared with the aggregate analysis, the only change worth noting was the negative slope of time in the second period for the Southern group. This means that the minor decline in income per capita seems to have had an effect on women's height in this group as well, but that it was compensated by increasing urbanization and wealth (younger cohorts are more urbanized and wealthier).

Multivariate analysis confirmed the net effect of urban residence (+0.25 cm) and the net effect of wealth (+0.21 cm per unit of wealth on a scale from 0 to 14) on average. These effects remained consistent from period to period and from group to group, despite some minor significant differences. The only striking change was that of urban residence in the Southern group: older women living in urban areas were shorter than rural women, a finding that needs to be further explored.

The multivariate analysis also confirmed the major differences by population group, the Sahelian group being 3.1 cm taller, the Eastern group being −2.3 cm shorter, and the Southern group being somewhat taller (+0.73 cm) than the average Central group. These effects remained consistent over time, despite minor changes, the most noticeable being a larger relative advantage of the Southern group in the later period.

Discussion

Our analysis is based on the hypothesis that major changes in income have an effect on nutrition and therefore on adult height. This effect was found in numerous places in the world, mainly on the positive side, where increasing income translated into increasing height. It was also found on the negative side, where decreasing income induced declining height in a number of crises, such as wars in Europe. Similar effects of decreasing income on worsening nutrition were documented in the Third World. [Brinkman et al. 2010] Note that no mechanism other than income and nutrition has yet been found as a determinant of changing

height, such as diseases or other causes, so that the correlations presented here have the value of robust evidence.

The African case differs in that it is a long term crisis, occurring independently of major wars, and on a very large scale, that of a whole continent. It gives an order of magnitude of the very severe economic crisis that sub-Saharan Africa went through from the mid 1970's to the mid 1990's, whipping out decades of positive secular trends.

The shortening of African women occurred despite regular improvements in child survival over the same period. [Ahmad et al. 2000; Garenne & Gakusi, 2006] Furthermore, we did not find evidence of a correlation between economic cycles and year of birth (i.e. the economic situation in prime infancy), but rather with time of the adolescence growth spurt. This indicates that fluctuations in income affected primarily the nutrition of adolescent girls. The biological effects of change in nutrition during adolescence remain poorly documented and deserve more research. We also need to know more about the many consequences of economic recession on food allocation in families, and on various behaviors which could have an effect on adolescent nutrition, such as sending youth to work for low wages instead of staying in school, increased work load, poorer care, forced marriage at an early age, and the numerous psychological factors that could induce negative health behavior.

Differences between urban and rural areas remain stable in our multivariate analysis even after controlling for wealth, time trends and genetic factors. What gives the city an advantage to nutritional status remains to be further explored. One possible explanation could be food diversity, likely to be greater when food is bought than when food is grown.

We addressed only trends in women's height, simply because no such data exist for men in DHS surveys. Adolescent men are usually more sensitive to changes in the food environment, so that one could expect even a greater effect of the economic recession on men's height than that found on women. This needs to be further explored when more data become available.

Secular trends in height have deserved much attention from economists and physical anthropologist, but very little from demographers. This is unfortunate since many of the best data in the Third World now come from DHS surveys. Demographers could also contribute significantly by bringing their expertise in the field, in particular by focusing on cohort effects which are often ignored by economists. Much research could be pursued along those lines in numerous countries and even in subgroups. A wide door is now open by these preliminary investigations.

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Table 1: Changes in income per capita and in women's height, sub-Saharan Africa (from reconstruction in 33 countries)

Area	Income per capita (GDP-PPP) (in 1990 USD)			Average women's height (cm)		
	Period-1		Period-2	Cohort-1		Cohort -2
	1950	1974	1994	1940	1967	1990
Absolute values						
All countries	823	1303	1038	157.3	158.7	157.5
Central	744	1193	905	157.3	159.1	157.4
Sahelian	642	749	731	161.7	161.8	161.1
Eastern	546	799	608	155.3	156.2	155.6
Southern	2051	3547	3014	158.7	159.2	159.7
Growth / Slope	1950-1974		1974-1994	1940-1967		1967-1990
All countries	+1.9%		−1.1%	+0.49		−0.49
Central	+2.0%		−1.4%	+0.68		−0.75
Sahelian	+0.6%		−0.1%	+0.02		−0.30
Eastern	+1.6%		−1.4%	+0.34		−0.26
Southern	+2.3%		−0.8%	+0.19		+0.19

Notes: GDP-PPP per capita from Maddison, 2010; Mean annual rate of economic growth recalculated from same data. Women's height from reconstruction of trends by cohort in 33 countries; Slope = mean absolute change (cm) per decade. Changes in slopes for women's height all significant with $p < 10^{-10}$, except for Southern region (no change).

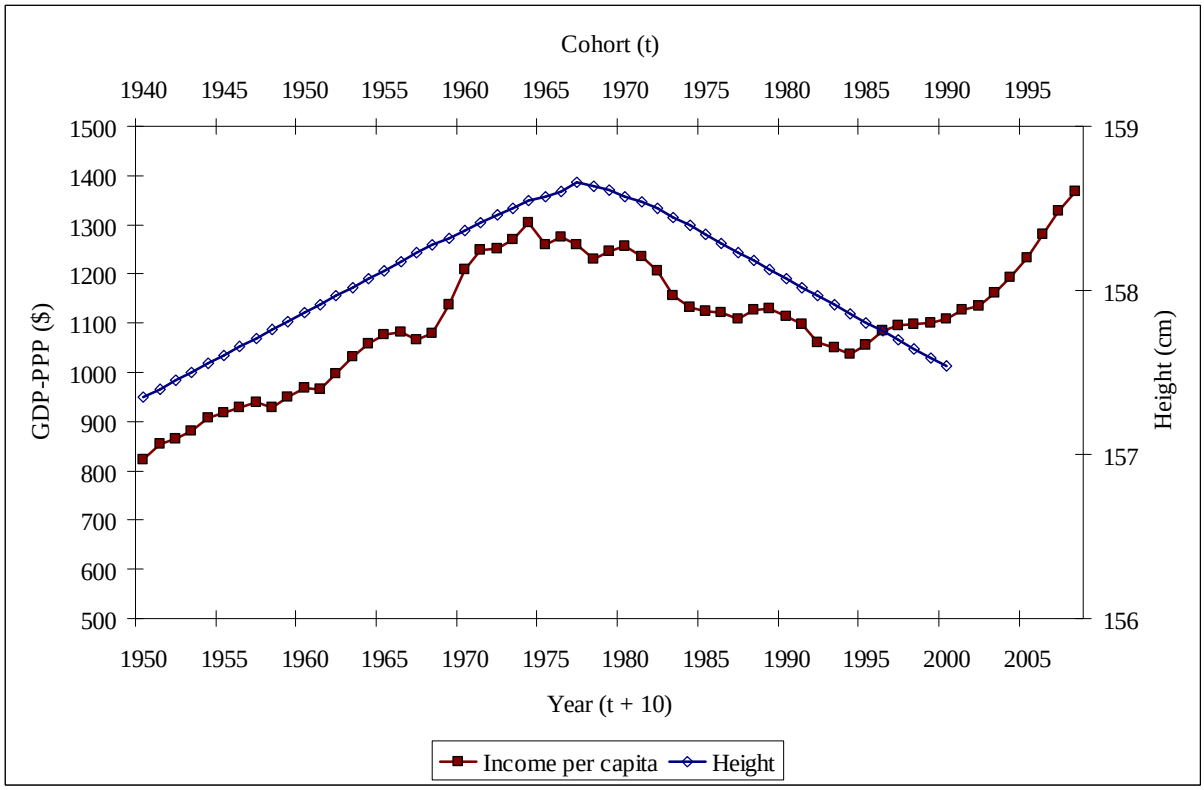
Table 2: Results of multivariate analysis of trends in female adult height

	Cohort 1 : 1940-1967		Cohort 2: 1967-1990		Time change	
	Coefficient	Standard error	Coefficient	Standard error	P-value	Signif
Coefficient of time						
Central	0.0406	0.0064	-0.1016	0.0026	0.0E-99	*
Sahelian	0.0214	0.0076	-0.0626	0.0041	0.0E-99	*
Eastern	0.0112	0.0079	-0.0513	0.0038	1.2E-12	*
Southern	0.0601	0.0093	-0.0272	0.0055	6.7E-16	*
Total	0.0355	0.0039	-0.0858	0.0019	0.0E-99	*
Coefficient of urban residence						
Central	0.5582	0.0694	0.6741	0.0403	0.149	
Sahelian	0.3762	0.0950	0.7053	0.0675	0.005	*
Eastern	0.1798	0.1025	0.3307	0.0618	0.207	
Southern	-0.6241	0.1569	0.0579	0.0970	0.000	*
Total	0.2413	0.0484	0.3649	0.0295	0.029	*
Coefficient of wealth						
Central	0.2076	0.0123	0.2484	0.0069	0.004	*
Sahelian	0.2181	0.0201	0.2163	0.0136	0.941	
Eastern	0.1547	0.0216	0.1656	0.0127	0.664	
Southern	0.1832	0.0212	0.1600	0.0129	0.349	
Total	0.2379	0.0084	0.2886	0.0050	2.1E-07	*
Net effect of population group						
Central (ref)						
Sahelian	2.9565	0.0468	3.2729	0.0323	2.7E-08	*
Eastern	-2.4407	0.0475	-2.2802	0.0297	4.2E-03	*
Southern	0.4837	0.0632	1.0551	0.0408	3.0E-14	*

Note: Regression equation was: height = A + B*Cohort + C*Urban + D*Wealth (for each population group). The last regression included all countries plus a dummy variable for groups.

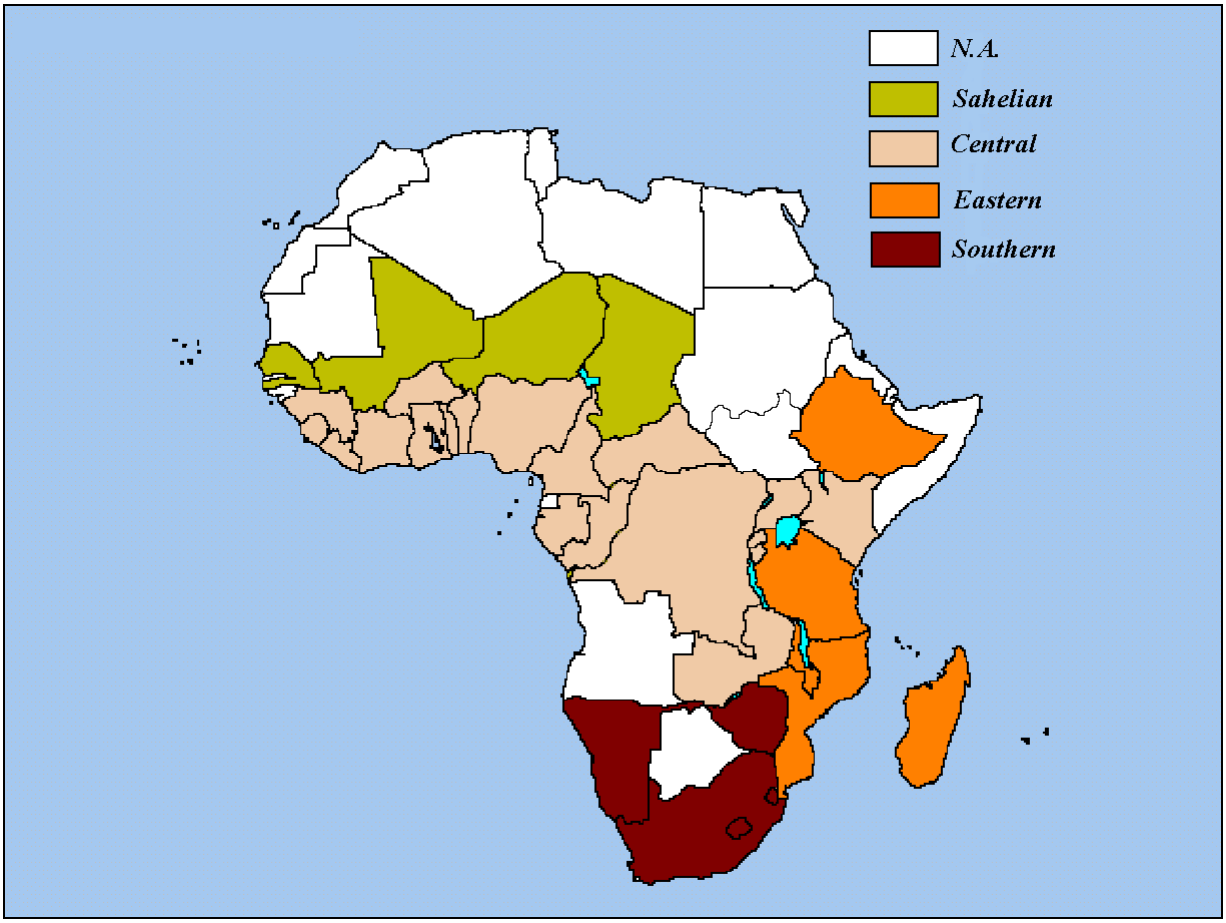
Figure 1

Period trends in income per capita and cohort trends in average women's height



Map 1:

Countries selected by large population groups



Annex 1. List of DHS surveys included in the study of trends in women's nutritional status

Group	Country	DHS-II	DHS-III	DHS-IV	DHS-V
Sahelian					
	Burkina Faso	1993	1999	2003	
	Chad		1997		2004
	Mali		1995	2001	2006
	Niger	1992	1998		2006
	Senegal	1993			2005
Central					
	Benin		1996	2001	2006
	Cameroon		1998	2004	
	Central African Rep.		1994		
	Congo-Kinshasa (RDC)				2007
	Congo-Brazza (RPC)				2005
	Côte d'Ivoire		1994	1999	
	Gabon			2000	
	Ghana	1993	1999	2003	2008
	Guinea		1999		2005
	Kenya	1993	1998	2003	2008
	Liberia				2007
	Nigeria		1999	2003	2008
	Rwanda			2000	2005
	Sierra-Leone				2008
	Togo		1998		
	Uganda		1995	2001	2006
	Zambia	1992	1997	2001	2007
Eastern					
	Comoros		1996		
	Ethiopia			2000	2005
	Madagascar		1997	2003	2008
	Malawi	1992		2000	2004
	Mozambique		1997		2003
	Tanzania		1996		2004
Southern					
	Lesotho			2004	
	Namibia	1992			2007
	South Africa		1998		
	Swaziland				2007
	Zimbabwe		1994	1999	2005