The significance of variations of human size dimorphism in stature in Europe in the field of health and well-being

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Abstract

Applying anthropometric indicators like stature and sexual stature dimorphism (SSD) to the field of health and well-being faces the difficulty of disentangling the influences of nature from nurture as well as the interaction between processes of selection and adaptation to changing environmental conditions.

In this paper the significance of variations and differentials of adult stature among males and females is discussed in light of previous historical and anthropological data together with new empirical evidence collected from diverse European populations over the 20th century. Specifically, it is aimed to elucidate the relationship between intergenerational changes and social differences in mean adult stature and mean adult SSD among European cohorts born over the 20th century.

For these purposes heights from modern health surveys were drawn together with a number of socio-demographic variables in order to approach the socioeconomic status of individuals while they were growing (i.e. at pre-adult ages). Multivariate regression techniques were applied to adjust series of SSD for different segments of the population.

In Spain SSD remained relatively low, with respect to modern standards among well-off populations, among cohorts that were exposed to structural deprivation at pre-adult ages, mainly during the first half of the 20th century. This result compares to higher values of SSD among English population since the beginning of the 20th century. In Spain socioeconomic status approached by the educational attainment of individuals mediated the correction of these deviations among subsequent cohorts. Middle-upper classes were systematically closer to normal SSD values, and they reached these values earlier in time. This mediation is only partially observed in England.

Our results point to a correlation of variations in SSD with both socioeconomic changes related to well-being standards at a nationwide level and SES differentials at the individual level which will be contrasted through the exploration of other European populations.

Introduction

Human height is an essentially heritable trait that has been subjected to the forces of adaptation and natural selection throughout the evolutionary history of humankind (Roberts, 1981). However, height has supplemented other traditional economic and health indicators as a measurement of the diverse dimensions of well-being and living conditions given its proven ability to respond to environmental influences (Tanner, 1978; Bielicki, 1986; Bogin, 1988). Hence, the consensus is that height variability between and within populations may be attributed to both genetic factors and external environmental influences, such as the level of nutrition (i.e., food quantity and diet quality) and exposure to illness. The extent to which potential inherited height is attained in adulthood depends on the balance between energy inflow and energy expenditures over the physical growth process during the first two decades of post-natal life. Balanced energy expenditures, particularly during the critical periods of infancy and adolescence, are expected to result in attaining the genetically inherited height, whereas unbalanced (i.e., negative) accounts may result in the failure to attain that biological potential. A wide gradient of physical maturation patterns and mean adult heights has been observed across populations (Eveleth and Tanner, 1990). In Europe, the mean height of Southern Europeans born at the end of the 1960s was still below the height attained by Northern Europeans born during the 1920s (Cavelaars et al., 2000). During the first half of the 20th century, Northern and Central European countries increased their mean height at a higher rate than Southern European countries, and the reverse occurred during the second half of the century (Hatton and Bray, 2010), which led to a convergence process across the different countries.

Sexual stature dimorphism (SSD) is an extensively documented issue within human biology and physical anthropology (e.g., Alexander et al., 1979; Gasser et al., 2000). Humans and most species of dimorphic mammals share similar patterns of height divergence between males and females throughout the physical growth cycle. For the most part, any differences are insignificant prior to puberty, and adult SSD typically results from a combination of increased growth rate and extended duration of growth in the larger-bodied sex (Willner and Martin, 1985). As men become taller than women on average, it is difficult to disentangle nature from the effects (if any) of nurture. The effects of nurture would include diverse components of the living conditions of the population.

Between populations, a ratio of 1.07-1.08 and absolute values of 12-13 cm was found to prevail among non-marginal habitats for both the economically developed and developing populations (Bogin, 1988; Eveleth and Tanner, 1990). Stini argued that the relative uniformity of SSD found between populations grown up under diverse environmental conditions responded to compensatory mechanisms. Specifically, he argued that males most likely grew more slowly than females under conditions of nutritional stress but that they also grew for a longer period of time in those specific contexts. The relatively small variations of adult SSD that have been found across populations should not be considered insignificant because variability in stature dimorphism is small when compared to other physical traits. For instance, body mass and skeletal mass have sex-specific ratios of 1.5 and 1.3, respectively, which results in males who are 50 percent and 30 percent larger (Garn, 1981). Thus, some authors have argued in favor of environmental influences on SSD, based upon small variations across populations (Tobias, 1975). For the most part this agrees with the aforementioned hypothesis that adverse environmental circumstances affect growing males more than growing females. Tobias proposed that populations that were reared under unfavorable environments should also display a lesser degree of adult SSD (thus compensatory mechanisms could only partially correct the environmental effects upon the growth of males and females). In turn, Eveleth (1975) was skeptical about the properties of SSD as a measure by which to judge the health, nutritional status or any other dimension of the living conditions of populations because of the potential influence of ethnic factors on the final outcomes (in agreement with this view, Alexander et al., 1979). In conclusion, using the SSD is particularly problematic in absence of detailed ethnic and socio-demographic information that will allow to control for potential confounding factors.

Studies of SSD variations within a population over time have not concluded unequivocally about the significance of those variations (detailed reviews in Gustafsson et al., 2007; Harris, 2009; Guntupalli and Baten, 2009). The plasticity of male and female height as a function of environmental conditions over time is controversial due to the limitations of the research infrastructure. Specifically, these limitations include inadequate data to construct series and/or the use of small, fragmentary and heterogeneous sources that are hardly representative of populations. In 20^{th}-century Europe, which is most likely the best documented case, secular increases in height among women have been lower than among males, whether height was measured in the study (Bodzsar and Susanne, 1998) or whether it was self-reported (Cavelaars et al., 2000). Cavelaars et al. analyzed height series from cohorts of males and females born between 1920 and 1970 in a number of Western European countries. They found that increases among males were generally higher and that, consequently, the gap between sexes increased with time. In other words, younger cohorts of Europeans displayed a larger SSD than older cohorts on average, coinciding with substantial improvements in living conditions.

In this paper, we address height differentials between males and females, dealing simultaneously with the intergenerational variations and the potential differences of the socioeconomic status (SES) of individuals. Such an approach may clarify the actual capacity of SSD to capture environmental influences as well as to refine the interpretations about the evolution of some key components of well-being that were based upon cohort height series in exclusive.

Data and methods

The sample of results presented below come from analyses performed on microdata of health interview surveys (HIS) from Spain (self-reported heights) and England (measured heights). Both HIS were conducted face to face and several more countries will be added to the final version of the paper following the same methodological specifications that are explained next.

The HIS utilized in this work are repeated cross-sectional waves (i.e. there is no follow-up with individuals over time). Microdata from several waves (Spain: 1987, 1993, 1995, 1997, 2001, 2003 and 2006; England 1993, 1998, 2003, 2008) were aggregated into one large dataset (N_{spain}=93,000; $N_{england}$=44,000). For Spain proxies, non-Spaniards and those aged under 25 and over 79 years were discarded. For England, the same age criteria was followed and only white population born in England is included. The use of subjects with ages 25 to 79 ensures that individuals have completed their physical growth and prevents random effects caused by small sample size at very old ages.

Self-reported height distributions (in Spain) follow a similar pattern by sex (not shown, available upon request). Standard deviations across cohort groups remain reasonably constant and close to the values observed in the distributions of measured heights among modern populations (Cole 2000).

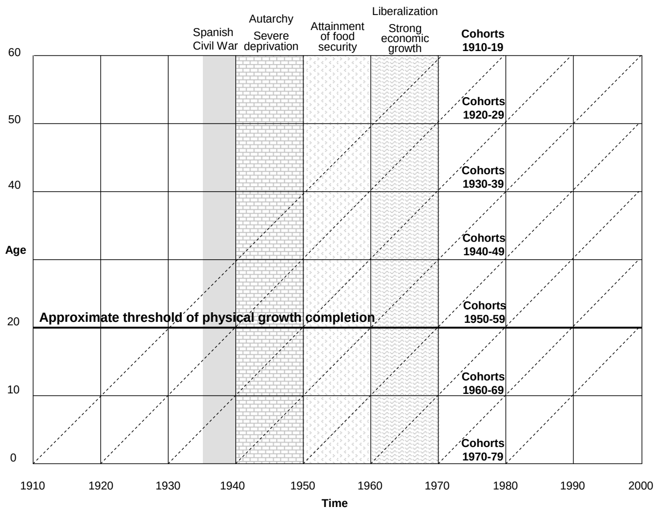
We ran multivariate regression models for each five-year cohort group. In these models, self-reported height is the dependent variable, and a binary variable for sex is set to capture cohort SSD in centimeters after age, education and several more covariates are partialled out. In the case of Spain, age is including in the regression models as a controller of misreporting as no shrinking effect related to aging is observed. In the case of England, age partially controls for shrinking effects within each cohort group but this effect is not controlled among older cohorts with respect to younger cohorts. This affects trends in height but to a much lesser extent trends in SSD as shrinking effects do not substantially differ between males and females.

As the bulk of sex differences in height originate after infancy (Gasser et al., 2000), and environmental conditions during adolescence may eventually explain differences in adult size dimorphism between generations (Van Wieringen, 1986: 315-316) the series are plotted against a double time scale: birth cohorts and an approximation to the estimated central year at puberty for each cohort group based on the evolution of the mean age at menarche in Spain over the 20th century.

Sample of preliminary results

Figure 2 presents a contextualization of the life cycle of the cohorts under analysis in Spain in order to ease the interpretation of results.

Figure 2. Historical framework of the life cycle of Spanish cohorts born between 1910 and 1979



Note. As adult height is assumed to be a cumulative result of the environmental conditions experienced during the physical growth cycle, the focus must be on the potential exposure to environmental disruptors during the first two decades of life. Accordingly, the most prolonged exposure to unfavorable environments (i.e. prior to the attainment of food security) was experienced by cohorts born between 1920 and 1939 (these cohorts are framed by a red rectangle in Figures 3 and 4).

Our results indicate that variations in SSD among Spanish cohorts born throughout the 20th century are associated with both changes in general living conditions at a nationwide level and socioeconomic differences within the population at a micro level (Figures 2 and 3). Cohort SSD in Spain remained relatively low among cohorts born between 1910 and 1939. The mean values of SSD observed among these cohorts are closed to those observed in England during a phase of deterioration of living conditions in the context of the industrialization process during the central decades of the 19th century (Figure 4). SSD subsequently increased due to a steeper growth of males with respect to females. This means that Spanish females did relatively better in terms of physical growth in hard times. In consequence, in our view, increases in SSD observed among younger cohorts of Spaniards cannot be strictly interpreted in terms of the social disadvantages of females, as suggested in previous studies (Costa-Font and Gil, 2008). Certainly, such increases in SSD had to do with a slowing down of the upward trend in cohort female height, but this also occurred in other Western European countries (Cavelaars et al., 2000) and in the United States (Komlos and Lauderdale, 2007: 209). Moreover that phenomenon occurred under diverse political and socioeconomic circumstances. At least in Spain, it seems plausible that if male growth was more susceptible to adverse living conditions, males might have also responded more positively to an improved environment. This adaptive behavior was previously proposed to explain the divergent trends in lean body mass between males and females (Stini, 1975). Besides, increases in adult SSD have been observed among other European populations during the 20th century (Kuh et al., 1991; Cole, 2000), thus supporting the hypothesis that females possess a better capacity to cope with stressful environments (Bielicki 1986; Demoulin, 1998).

In England, the results do not display coupled increases in mean adult height and SSD over the same approximate period of time that was examined for Spain. This has also been observed in 20th-century Sweden. In a collection of samples from Swedish populations, Gustafsson et al. (2007) observed an increase in both male and female stature during the 20th century. The authors argued that this result was most likely due to improved living conditions, but it was not accompanied by significant changes in SSD. The authors concluded that male stature is not more sensitive to environmental changes than female stature. However, it could be argued that the environmental changes in that study were not of significant enough magnitude, particularly when compared with those observed in Spain. In other words, SSD may remain more stable once certain living standards (and mean stature) have been attained. In fact, Gustafsson et al. did find significant increases in SSD in the 20th-century samples compared to the pre-18th-century samples in Sweden, as other historical works have also found (Baten and Murray, 2000; Koepke and Baten, 2005). Illustratively, in 19th-century England (and Wales) we also found low SSD figures among a sample of individuals from lower classes and it is likely that subsequent increases in mean SSD took place over the second half of the 19th century to reach modern standards during the first third of the 20th century. Interestingly, although at different levels, both countries, Spain and Sweden, experienced a decline in SSD among cohorts that were exposed to war effects during their infancy and/or adolescence.

Cross-national comparisons based on this indicator permit to approximate differences in the environmental conditions. In this case, the results illustrate the transitory delay of Spain in key components of well-being such as the net nutritional status of the population. Eventually, this biosocial approximation to well-being might permit to measure insults and deficiencies in these components of well-being more accurately than indicators that capture the amelioration of the situation in terms of fatal outcomes (i.e. mortality) which may or may not be related to an effective improvement of endogen factors of the living standards.

Figure 3.Mean cohort SSD (cm and ratio). Spain, 1910-1979.

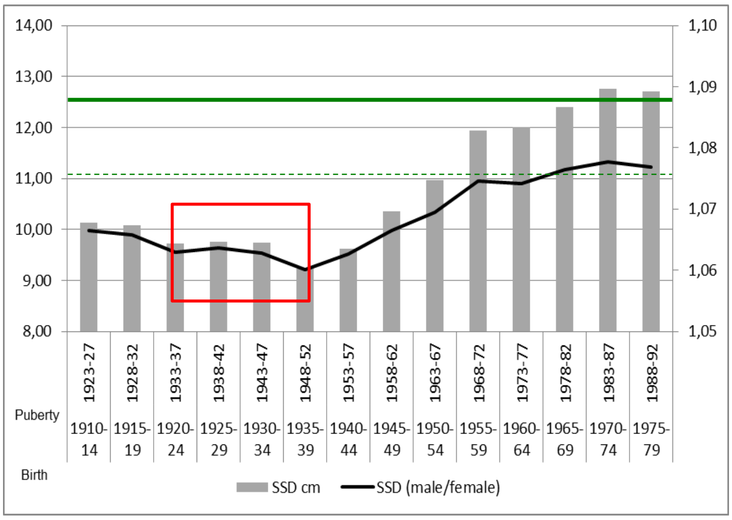


Figure 4.Mean cohort SSD (cm and ratio). Spain, 1910-1979

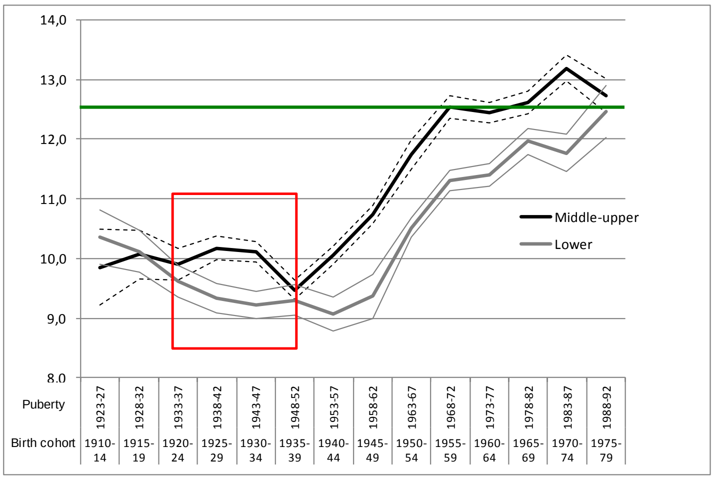
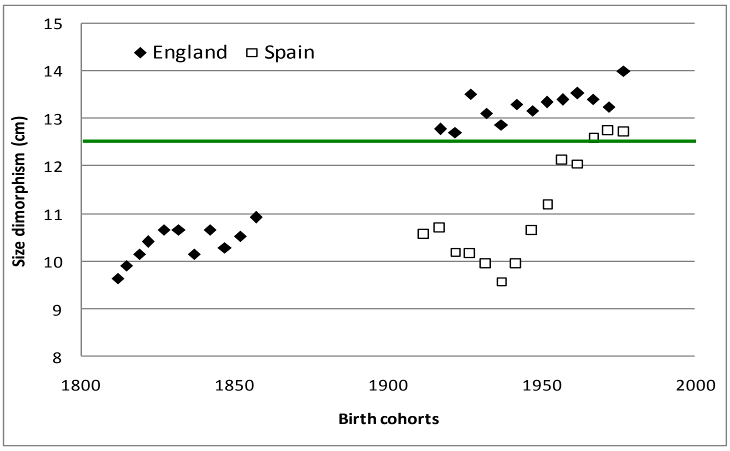


Figure 5. Mean cohort SSD in Spain and England. 1812-1979



Note. SSD over the 20th century is from the author's own calculation on HIS microdata. SSD in 19th -century England refers to England and Wales (cohorts born 1812-1857) and the results come from Jonhson and Oaxley (1995). The data correspond to heights from a register of habitual criminals compiled by Scotland Yard. The register contains information on 8,6I2 males and 3,552 females. Authors argued that these heights were broadly representative of the lower half of the English working class. Importantly, heights did not display truncation bias.

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