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Anthropometric geography applied to the analysis of socioeconomic disparities: cohort trends and spatial patterns of height and robustness in 20th-century Spain

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Abstract

Anthropometrics have been widely used to study the influence of environmental factors on health and nutritional status. In contrast, anthropometric geography has not often been employed to approximate the dynamics of spatial disparities associated with socioeconomic and demographic changes. Spain exhibited intense disparity and change during the middle decades of the 20th century, with the result that the life courses of the corresponding cohorts were associated with diverse environmental conditions. This was also true of the Spanish territories.

This paper presents insights concerning the relationship between socioeconomic changes and living conditions by combining the analysis of cohort trends and the anthropometric cartography of height and physical build. This analysis is conducted for Spanish male cohorts born 1934–1973 that were recorded in the Spanish military statistics. This information is interpreted in light of region-level data on GDP and infant mortality.

Our results show an anthropometric convergence across regions that, nevertheless, did not substantially modify the spatial patterns of robustness, featuring primarily robust northeastern regions and weak Central-Southern regions. These patterns persisted until the 1990s (cohorts born during the 1970s). For the most part, anthropometric disparities were associated with socioeconomic disparities, although the former lessened over time to a greater extent than the latter. Interestingly, the various anthropometric indicators utilized here do not point to the same conclusions. Some discrepancies between height and robustness patterns have been found that moderate the statements from the analysis of cohort height alone regarding the level and evolution of living conditions across Spanish regions.

Keywords

Height; robustness; anthropometric geography; spatial disparities; cohort trends; living

Introduction

Anthropometric measures have been used in developmental and historical studies to understand the impact of environmental factors on the living conditions of individuals and populations. Stature alone or combined with other physical measures is the main parameter used in these approaches.

The final height that an individual attains in adulthood results from two types of determinants: 1) genetic determinants, in that genes establish a maximum potential for each individual, and 2) environmental determinants (these taken in a broad sense), in that socioeconomic and epidemiological factors determine to what extent that biological potential will be attained (Silventoinen, 2003).

At a population level it is apparent that genetic changes associated with natural selection occur over a much longer time period than social and historical changes. For instance, in the past century, covering just 3–5 generations, there have been substantial changes in stature that genetic change cannot fully explain. For this reason economic and environmental processes have been used preferably to explain the anthropometric variations observed over time (Fogel and Costa, 1997). This said, it must be acknowledged that demographic change in itself may play some role. Selection forces from the interaction of mortality, fertility and fecundity may influence inter-generational trends in height and other physical traits especially of populations that experienced rapid declines of vital rates during the initial stage of the demographic transition (Courtiol et al, 2013; Moorad, 2013). For instance, at very high levels of pre-adult mortality and/or short-term demographic shocks, the selection of taller and stronger survivors might theoretically result in a taller-than-expected adult population due to living conditions (Alter, 2004; Bozzoli et al., 2009). Though plausible, these scenarios have been supported by little empirical evidence so far (Gørgens et al., 2012). More commonly, it is accepted that structural deprivation, prolonged scarcity or frequent epidemics leading to high mortality levels also tend to produce shorter populations, both as pre-adult mortality and height are a reflection of the biological status of the population. As such they have a good number of common environmental determinants (nutrition or the degree of exposure to illness). To be sure, this is the case of mortality contexts in 20th-century Europe whereby the stunting effect of poor living conditions at childhood clearly dominates any possible selection effect of pre-adult mortality on the average height of cohorts in adulthood (Bozzoli et al., 2009; Spijker et al., 2012). Therefore, we may expect taller populations to exhibit lower mortality which also seems to apply among individuals within contemporary societies (Waller, 1984).

The relationship between the patterns of human growth and the environment were firstly established by auxology (the discipline that studies physical growth) and human biology (Bogin, 1988) and subsequently integrated in the historical debate from the 1970s through the so-called technophysio evolution theory (Fogel and Costa, 1997; Floud et al. 2011 for an updated view; review articles with citation of early works in Steckel 2009 and 2013). This theory addresses the dramatic changes in survival and health which have taken place during the last three centuries. With regard to body size, height in particular, this theory underlines the role of socioeconomic changes for the improvement of the net balances of energy inputs

(quantity and quality of food intake) and major energy outflows such as exposure to illness. As stated by auxology an adequate balance between energy inputs and energy outflows contributes to a normal growth pattern and makes the attainment of the genetically inherited stature likely. Conversely, an energy imbalance associated with prolonged environmental stress during the growth cycle (e.g., due to chronic malnutrition or continuous exposure to illness) may eventually result in losses from the potential inherited height (Bogin, 1988). Accordingly, height variations between genetically uniform populations and over time may be interpreted as functions of these environmental factors. This has made human stature a widely used indicator to study different dimensions of well-being as well as the positive or negative effects that socioeconomic processes have had on populations over time (e.g. Komlos and Baten, 2004; Floud et al., 2011; Martínez-Carrión, 2012). Additionally, a number of studies have examined the relationship between cohort height and other developmental indicators such as infant mortality and GDP (e.g., Akachi and Canning 2007; Bozzoli et al., 2009; Arcaleni and Peracchi, 2011).

To a much lesser extent, heights have also been used to study spatial disparities within countries (Tassenaar, 1995; Salvatore, 2004; Arcaleni, 2006), and to our knowledge, only a few works have used, together with height, other anthropometric measures or indexes such as the Body Mass Index (BMI) and the Robustness Index (RI) to study these issues. When this was done, the time span was very limited and therefore the possibility to analyze time-cohort trends. Recently, Peracchi and Arcaleni (2011) explored the relationship between disease burden (captured by infant mortality) and economic conditions (represented by GDP or per capita consumption), height and BMI among six cohorts of modern Italian men born between 1973 and 1978. Some data on physical robustness (height, weight and thorax circumference) were provided for the study of the labor conditions of some 20th-century populations (Cleveland, 2011).

In this work we analyze regional anthropometric data from Spanish male cohorts 1934–1973 to obtain further insights on the evolution of socioeconomic disparities and their effects on the biological status of the population. To do this changes in the anthropometric geography of Spain over time are examined through continuous series of cohort adult height, BMI and RI for Spanish regions. The results are discussed in light of socioeconomic processes in the mid-twentieth century.

Spain stands out among current affluent Western societies for its rapid and intense development and its progress towards high development levels during the 20th Century. Diverse indicators reflect the magnitude of socioeconomic changes in this country over that period (Ramiro-Fariñas and Sanz-Gimeno, 2000). Life expectancy at the turn of the 20th century was barely 35 years¹; in 1950, it had risen to 62 years and in 2000 it was approximately 79, among the highest in the world (INE, online database). Trends in height also illustrate this steep pace of improvement in key components of well-being. It is estimated that male Spaniards born during the 1970s were approximately 9 cm taller on average and females were approximately 6 cm taller than those born during the first decades

¹In 1900, life expectancy in other European countries was 32.4 years in Russia, 42.8 years in Italy, 44.4 years in Germany, 47.4 years in France, 48.2 years in the UK, 49.9 years in the Netherlands and 54.0 years in Sweden (Livi-Bacci, 1992).

of the 20th century (Spijker et al., 2012), one of the steepest increases documented among Western European countries (Hatton and Bray, 2010) (Figure 1).

Paralleling the improvement of these bio-sanitary indicators and likely propelling them, the total fertility rate declined from approximately 4.5 children per woman in 1900 to 2.5 in 1950 (Cabr, 1999) and 1.25 in 2001 (Bernardi and Requena, 2003). The completed fertility of Spanish women at the end of their reproductive life is estimated to have declined from 3.3 children per woman (1901 female cohort; Fernndez Cordn, 1986) to 2.4 children per woman (1946–50 cohort; Cabr, 1999) and 1.76 (1956–60 cohort; Nicolau, 2005).² Assuming the conventional 30-year interval elapsed between generations, such decline implies that, on average, Spaniards born during the 1970s grew up in households 30% smaller in size than those born during the 1930s (the array of cohorts studied in this work is 1934–73).

Finally, a composite measure of well-being, the Human Development Index (HDI) which combines three basic dimensions of human development (health, education and income) was estimated at 0.363 in 1900 (Escudero and Simn, 2003), whereas it was 0.839 in 2000 (IHDI, online)³.

These changes exemplify how different the life courses were among the Spanish population born throughout the 20th century, beginning with a population that experienced hardship and severe deprivation and ending with a population that grew up in an affluent society. This contrast between generations is accompanied by important spatial disparities.

During the intense economic growth process experienced by the country between 1950 and 1975, industry, services and population were concentrated in the most dynamic regions (e.g., Madrid, Catalonia or the Basque Country), which is reflected by the regional distribution of GDP (Carreras, 1990) and also by a regional gradient in bio-sanitary indicators such as life expectancy (Blanes, 2007) and height. Regarding the latter, Martnez Carrion (2005) analyzed region-level heights in the 1950s and 2000s, concluding that a convergence across regions had taken place. However, the precise evolution of anthropometric patterns as a function of the economic trajectories of the Spanish regions deserves further study, as does the relationship between the height gradient and other anthropometric measures.

This work aims to review and discuss the socioeconomic development of Spanish regions over the middle decades of the 20th century in light of continuous cohort trends of adult height, body mass and physical robustness. These trends and the evolution of the anthropometric geography of Spain are compared to the evolution of spatial disparities in two traditional developmental indicators, infant mortality (a widespread indicator of the disease environment) and GDP (an indicator of economic conditions). Our study makes

²Fertility in the most economically developed areas of the country which also transited earlier towards a modern demographic regime was systematically lower during the first half of the 20th Century. For instance, in Catalonia (Northeast Spain) the total number of children per woman was 2.1 (1901–04 cohort) whereas it was 3.3 in the whole country. Among subsequent female cohorts, the figures tended to converge across regions. For example, women in Catalonia born 1946–50 gave birth to 2.26 children on average (the figure for Spain was 2.45) and 1.97/1.76 respectively among women born 1956–60 (Cabr, 1999; Nicolau, 2005).

³HDI ranges from 0 to 1. A value of 0.8 is usually accepted as indicative of high development, whereas values under 0.5 are indicative of low development.

three main contributions. First, it demonstrates the ability of anthropometric geography to shed light on socioeconomic disparities. Second, it illustrates how socioeconomic disparities within a country can be analyzed from the spatial (i.e. inter-regional) and the demographic (i.e. inter-generational) perspectives simultaneously. Finally, it contributes to the specific literature on anthropometrics by comparing height patterns with patterns of two composite anthropometric indexes: body mass index (BMI) and robustness index (RI). Discrepancies between these indicators are of particular interest since they may show determinants of the biological status of the population infrequently appreciated in contextual analyses.

The paper contains three additional sections. The data and methods section describes our sources and the analyses performed. The results section presents a selection of materials from the trends and cartography that were produced as well as the results from the analytical tools used here, including multivariate linear regression and changes in the variation coefficients of the indicators involved in the study. The paper concludes with a discussion section.

Data and methods

Anthropometric data

Country-level and region-level anthropometric information were obtained from the military statistics of the Spanish Statistic Yearbooks. These statistics summarize individual data obtained from males during compulsory military service in Spain, which lasted until 1995.⁴ To our knowledge, no previous study has systematically exploited these data. Although the yearbooks have been published in Spain since the middle of the 19th century, those valid for the construction of continuous cohort series and anthropometric cartography have been produced since 1955.

The information is listed according to enlistment year and does not report the birth years of the recruits. Therefore, birth cohorts were determined as a function of the age at enlistment and the enlistment year. The enlistment age was 21 in 1955, thus the first cohort under analysis is 1934. Although the enlistment age changed several times in subsequent years, every cohort had to perform military service, thus every subsequent enlistment corresponded to a birth cohort, resulting in a cohort span of 1934–1973.

The anthropometric information provided in these statistics consists of relative distributions (i.e., percentages) of stature (in centimeters), weight (in kilograms) and chest circumference (CC, in centimeters). The data were tabulated in five-unit intervals, thus we calculated weighted averages using the central value within each interval across the distribution. Open intervals were assumed to have a length of five units. The lower limits of the open intervals varied, but this does not substantially affect our results because 1) variations tracked with the trend over time and 2) the percentage of recruits within these open intervals remained

⁴The degree to which these data are representative of the overall male population decreased since the beginning of the 1990s, as an increasing number of individuals opted for social service instead of military service. These individuals were not included in the military statistics, or at least they were not measured as illustrated by the increasing percent of missing cases reported in the sources. This compels us to omit the results on thorax circumference and RI for the last cohort group analyzed in this work (1969–73). Thus, the cohort group 1964–68 was chosen to close the map series.

very low. Although some departures from normal distributions are observed, the data seem to be adequate for the purposes of this work (Figure 2).

The BMI and the robustness index (RI) are two summary measures of the average physique of a population. BMI is the ratio between the mean weight (in kg) divided by the square of the mean height (in meters). The categories commonly accepted for this index are *underweight* ($<18.5 \text{ kg/m}^2$), *normal weight* ($18.5\text{--}24.9 \text{ kg/m}^2$), *overweight* ($25.0\text{--}29.9 \text{ kg/m}^2$) and *obese* ($>30.0 \text{ kg/m}^2$). RI is determined by subtracting the sum of weight (in kg) and chest circumference (CC, in cm) from height (in cm). Lower RI scores indicate a greater robustness, potentially resulting from a relatively short average height or from relatively high values of weight and CC. This index was originally constructed as a fitness measure for the screening of conscripts and workers in physically demanding positions⁵. Subsequently, anthropological and developmental studies also made use of this measure because of its straightforward nature and its relationship to economic circumstances (see, for instance, Bhattacharya et al., 1981; Pandey, 2006). RI categories have also been established, namely, 0–10 (very sturdy); 11–15 (sturdy); 16–20 (good); 21–25 (average); 26–30 (weak); 31–35 (very weak); >35 (poor)⁶.

The mean values of height, BMI and RI were computed for five-year cohort groups⁷. These means were compared to those from some previous works that used local-level microdata. Our averages fall solidly within the range of those obtained for different areas of Spain (Martínez Carrión, 2009).

As weight and, to a lesser extent, CC may respond to short-term environmental influences rather than to cumulative environmental influences over time, at a contextual level, the correlation between height and weight is expected to be lower than the correlation between height and CC and that between weight and CC (Table 1). Additionally, the association between height, body mass and robustness appears to be greater among the older cohorts analyzed here.

It can be noted that the usual categories of BMI and RI do not apply in this study because the range across regions is not sufficiently large (i.e., we do not find obese regions vs. underweight regions as the BMI of each region is comprised of many individuals who, on average, tend to possess a normal weight). Therefore, these indicators are mapped in intervals of 0.5 and 2 units, respectively. This allows us to capture significant variations in mean BMI and RI between cohort groups as well as regional disparities. For instance,

⁵This index is also known as the body build index or the Pignet index in reference to the French army doctor Maurice Charles Joseph Pignet who first utilized it at the beginning of the 20th century.

⁶The meaning of these categories was adapted by the Spanish army as follows: *very strong, strong, good, intermediate, weak, very weak, pathologic problems* (Guillén-Rodríguez, 1959). At the end of the 1930s, the mining company Diamang in the colonial state of Angola set 33 as the threshold for acceptance or rejection of workers, as this score was indicative of extreme weakness (Cleveland, 2011: 75–77). The mean RI in a sample of 27 modern Onge females (out of a population of 95 people) in Little Andaman (India) was 23.91 (Pandey, 2006). Bhattacharya et al. (1981) found that RI averaged 38.28 among 27 adult males of an Indian rural community in Mirpur with clear traces of undernutrition. As expected, no Spanish region had an average below the normal RI values, and our data do not indicate the RI distribution of the population.

⁷The average of 1955–1959 enlistments (the 1934–38 cohort) is derived from three years of data because regional data were not provided for 1956 and 1957. The average of 1970–1974 enlistments (the 1949–53 cohort) is a three-year average (1970, 1973 and 1974). The enlistment years 1971 and 1972 were discarded because of the strong decreases observed in all three anthropometric measures. This may be related to tabulation errors, or more likely, to the earlier age at measurement.

keeping weight constant at 60 kg, a 2-cm change in height (e.g., from 166 cm to 168 cm) results in a decrease in BMI from 21.77 to 21.25. Keeping weight and CC constant at 60 kg and 80 cm, respectively, a 2-cm change in stature (from 1.66 to 1.68) leads to an increase in RI from 26 to 28.

There is a final necessary observation about the data source concerning the nature of the geographical information. These aggregate statistics were formed by a central statistical commission that compiled, reviewed and aggregated the individual information sent from the province-level *Junta de Clasificación y Revisión* (so called since 1924 and formerly known as *Comisión Provincial* or *Comisión Mixta*). In the individual records, the geographical information provided is the place of birth of each recruit, but we have not been able to confirm that the final classification and aggregation of the individual records was made by place of birth and not place of recruitment. Place of recruitment was not specified in the source material, but could be implied by the organization of conscripts' records. As it is obvious that one or another system may influence the interpretation of results, we have accounted for both possibilities and therefore the potential bias caused by this fact is discussed in the last section of the paper. The so-called anthro-po-demographic regions utilized in the source roughly coincide with the current administrative structure of Spain (Figure 3).⁸

GDP and infant mortality data

These data were collected for three cohort groups: 1934–38, 1949–53 and 1969–73 (i.e., per capita GDP and m_0 correspond to the birth years of the conscripts).

GDP data come from Alcaide (2003), one of the few available estimates of regional GDP for the first half of the 20th century in Spain, which has been regarded in previous review work as indicative of the regional patterns and trajectories of economic development in this country (Carreras et al. 2005). As Alcaide's work provides GDP data every five years, averages between the two dates were used when necessary. For instance, the GDP associated with the 1934–38 cohort is an average of the 1935 and 1940 GDPs divided by the average mid-year populations of 1935 and 1940. As Alcaide's figures correspond to the current administrative regions, we merged GDP and population data to compute per capita GDP for the anthro-po-demographic regions.

Infant mortality rates were drawn from Gómez-Redondo (1992). As her data were originally provided by provinces, they had to be fit to the regional setting of the military statistics. As provinces within any region differ in size, population and socioeconomic characteristics, the

⁸The data are provided in anthro-po-demographic "zones" and "regions" (Hoyos-Sainz, 1942). Regions are more convenient for our purposes since they better approximate the current administrative structure of Spain. Anthropometric zones were discarded because they were too broad for our purposes. For instance, the Northern Zone includes Asturias, Cantabria, País Vasco and Navarra. The equivalence between the anthro-po-demographic regions and the current autonomous regions of Spain is as follows (current regions appear in parentheses): *región Galaica* (Galicia), *región Cántabra* (Asturias and Cantabria), *región Vasca* (País Vasco), *región Aragonesa-Riojana* (Aragón, La Rioja and Navarra), *región Castellano-leonesa* (Castilla-León) *región Catalana* (Catalunya and Illes Balears), *región Levantina* (Comunitat Valenciana and Murcia), *región Extremeño-manchega* (Extremadura and Castilla-La Mancha) and *región Andaluza* (Andalucía). Note that Hoyos' criterion results in some socioeconomic and cultural caveats. For instance, *región Levantina* includes the current autonomous regions Comunitat Valenciana and Murcia. Per capita GDP was systematically higher in the former during the central decades of the 20th century, and Murcia was economically more similar to the southern region of Andalusia. Also, most of Comunitat Valenciana speaks Catalan, thus making it culturally closer to *región Catalana*.

rates were weighted by the number of live births recorded in each province. Data on live births were obtained from the historical vital statistics of the Spanish Population (MNP) (INE; online). Additionally, as we are working with five-unit birth cohorts, five annual mortality rates by province were averaged to obtain the appropriate rate for each cohort.

The results of this harmonization between sources are presented in Table 2. This table contains two sections, GDP and infant mortality with three columns for each section and cohort group: 1) absolute value or rate, 2) relative value, with Spain equaling 100, and 3) the ordinal rank among Spanish regions. Between 1930 and 1970, the economic rankings exhibited little variation, with Madrid and some northeastern regions consistently ranked at the top. With few exceptions, infant mortality was also lower in those regions. Actually, GDP and m_0 maintained a strong linear relationship throughout the period analyzed here, with few exceptions (Figure 4). Madrid, a markedly urban region, had high GDP and high infant mortality levels during the central decades of the century. This most likely resulted from an urban penalty until improved sanitation and hygiene conventions and facilities were adopted and disseminated in subsequent phases of the urbanization process in Spain (Reher, 2001). This speculation fits with the observation that by the middle of the 1970s, Madrid was already among the regions with lower infant mortality rates.

Anthropometric series and cartography are supplemented with the analysis of the coefficient of variation of all the indicators involved the study, and with a series of multivariate regression models where height, BMI and RI are regressed on per capita GDP and infant mortality. Eventually, the strong association between GDP and m_0 makes the regression coefficients of m_0 insignificant as a regressor of the anthropometric outcomes. This analysis was performed using OLS regression in which both GDP and m_0 were transformed into their natural logarithms.

Results

The average stature of Spanish males increased approximately 9 cm (or 5.4 percent) from the 1934 cohort to the 1973 cohort. The average weight increased from 62 kg to 69.4 kg (or 11.9 percent), and the average CC increased from 87 to 89 cm (for the 1964–68 cohort, or 2.3 percent). BMI and RI do not exhibit a uniform trend over time due to the changing relationship between their components. BMI rose among the 1934–48 cohorts and decreased among subsequent cohort groups due to the strong increase in mean cohort height. Robustness increased among the 1934–48 cohorts due to limited progress in stature and proportionally higher increases in weight and CC. This trend was reversed among cohorts born after 1949, due to the dramatic increase in cohort height observed during the second half of the 20th century.

The anthropometric map of Spain became progressively more homogeneous over the life courses of the aforementioned cohorts (Figure 5). For instance, the height difference between the tallest region (*región Vasca*) and the shortest (*región Andaluza*) was approximately 4 cm among older cohorts. This difference decreased by more than half among cohorts born at the beginning of the 1970s (less than 2 cm between the tallest and shortest regions at the time, *región Aragonesa-riojana* and *región Galaica*, respectively)

(Figure 6). Therefore, short regions grew more than tall regions during the central decades of the 20th century, a trend that was also observed in neighbouring countries (Arcaleni, 2006). Regional differences in mean weight and CC also lessened, which altogether led BMI and RI to converge across regions.

Despite this anthropometric convergence, spatial patterns remained quite persistent, and few regions changed positions in the ordinal ranking over the course of the 20th Century, with Spain consisting of a northeastern arch of tall and robust regions and a group of shorter and weaker central-southern regions. This pattern disappeared for BMI but remained true for stature and RI among cohorts born at the end of the 1960s (Figure 5).

As for the relationship between anthropometrics, GDP and m_0 , regions with short average heights have relatively low GDPs and relatively high infant mortality levels, but these associations are somewhat ambiguous among tall regions. On the one hand, tall regions exhibited a broad range of infant mortality (for instance, during the 1930s, m_0 in the Canary Islands and Madrid was over 120 per thousand, whereas it was 91 and 82 per thousand in *región Vasca* and *región Catalana*, respectively⁹). On the other hand, we find that the Canary Islands were historically tall but had a relatively low GDP. BMI and RI partly resolve these paradoxes in that these indexes group the Canary Islands with the less-developed regions (i.e., poorly nourished) and Madrid with the high-infant mortality regions during the first stage of the modern process of urbanization.

Finally, although the anthropometric convergence across Spanish regions was already occurring among cohorts born during the 1940s, the process gained momentum among cohorts born during the 1950s and the 1960s, thus matching an effective reduction of economic disparities (Figure 7). However, economic and sanitary disparities remained significantly higher than anthropometric disparities as indicated by the coefficients of variation in Figure 7. Furthermore, the explanatory ability of GDP (good explanatory ability for cohort height but nonexistent ability for BMI and RI, likely due to the different temporal nature of the variations of their components) and m_0 decreased over the life course of the cohorts born after the 1950s (this is indicated by both the regression coefficients and R^2 in Table 3).

Discussion

This work analyzed the evolution of the anthropometric geography of Spain among male cohorts born over the central decades of the 20th century by examining adult height and composite indexes of body mass and physical robustness. These data were interpreted in light of socioeconomic disparities captured by GDP and infant mortality.

In our view, the strong anthropometric disparities that were initially observed across regions resulted from a long-term process of differentiation that, at least in the case of height, can be traced back to the second half of the 19th century (Gómez-Mendoza and Pérez-Moreda, 1985). To be sure, Spanish regions appeared in a very similar ordinal ranking (to that

⁹The latter is mainly due to the very low infant mortality rates in the Balearic Islands, 72.3 per thousand in 1934–38 (Gómez-Redondo, 1992).

observed among cohorts 1934–38) of height among cohorts born 1875–1934 (Quiroga, 1998 and 2001). This ordinal ranking of statures remained headed almost invariably by the Basque Country, Catalonia and the Canary Islands until the middle of the 20th century, and the remaining positions also remained largely stable.

All three anthropometric indicators, height, BMI and RI converged across regions over the period analyzed here, which was particularly the case among cohorts born between 1950 and 1960. This is in accordance with the existence of a compensation effect among relatively worse-off populations. These populations would respond more positively to improvements in environmental conditions (Wolansky, 1985). Structural scarcity in Spain came to an end during the 1950s, which was followed by a diversification of foodstuffs during the 1960s and the 1970s, thus representing a nutritional transition (Cussó, 2005). Additionally, exposure to illness was dramatically reduced as hygiene measures and sanitary provisions were substantially improved.

Nevertheless, some of our findings need to be interpreted with caution since taller than average regions such as the Basque Country, Catalonia or Madrid were also the main destinations of internal migration flows which were particularly intense during the 1950s and the 1960s (García-Barbancho and Delgado-Cabeza, 1988). Also, within regions, these flows tended to provoke rural depopulation (Collantes et al., 2013). Although the empirical evidence in this regard is partial and sparse, previous studies indicate that migrants are relatively tall with respect to either those who stayed or those born in the destination place (Mascie-Taylor, 1984; Danubio et al., 2005; Cámara, 2007:300; Szklarska et al., 2008)¹⁰.

It is unfortunate that few and highly incomplete sources are available in Spain to improve precision on this issue. Some military records indicate the province of enlistment and the province of birth, but this is not sufficient to disentangle the effects of migration on the anthropometric patterns as the age at migration is unknown. In other words it is not possible to determine whether migrants' heights fully reflect the original environment or also partly capture the new environment at destination. Some scenarios can be hypothesized notwithstanding.

If migrants were systematically taller than non-migrants and/or taller than the natives at their destination, that might cause the anthropometric disparities across regions to increase. In Spain, the cohorts born during the 1930s and the 1940s exhibited the most intense migratory flows as they presumably migrated during the 1950s and the 1960s. As a consequence, a portion of the large initial disparities and the slow pace of convergence among those cohorts might be due in part to the aforementioned selective effect. Also, some unexpected results might have to do with this, as the coexistence of tallness, low robustness and high infant mortality in Madrid among the earlier cohorts analyzed. In Madrid selective immigration might have produced high mean heights without a significant improvement of living

¹⁰Cámara (2007:300) reported that the average height of 30 migrants from the Andalusian town of Santa Fe (province of Granada) whose military records were filled in Catalonia and sent to that town was 1,67 m whereas the mean of the corresponding enlistments in Santa Fe was 1,66 m (n=417). These recruits were born between 1940 and 1952 and they were measured between 1959 and 1963 thus coinciding with the peak of migration from Andalusia to Catalonia. That migration is selective is also exemplified by the socio-demographic profile of the returned people. At the end of the 1990s Andalusian returnees were younger and owned a higher level of education by age than the average Andalusian population (Rodríguez et al., 2002).

standards. The latter is suggested by low BMI and RI in Madrid among the earlier cohorts analyzed. Other economically developed regions could experience this, but in such case the effect was buffered by either a better nutritional status of natives, better living conditions among the immigrants or a larger dispersion in living conditions within the region. We must not forget that Madrid is a uniprovincial region whereas other urban provinces such as Barcelona (in Catalonia) or Biscay (in the Basque Country) belong to regions with several provinces.

In the main and notwithstanding, we believe that the trends and patterns found in this work have more to do with socioeconomic factors than with migratory flows in themselves. On one hand, it is worth noting that not all the relatively tall regions were net immigrant regions. On the other hand, net migrant regions such as Castille-Leon experienced an outstanding and continuous progress in height and robustness that spanned cohorts born from 1940–70 (i.e., cohorts that essentially ceased their physical growth between 1960 and 1990), a period with a varying intensity of migratory flows. Finally, previous works found that until the second half of the 1960s there were many net-migrant provinces but few net-immigrant ones. Thereafter a diversification of origins and destinations occurred (Cardelús and Solana, 2003) and therefore the potential selection forces abovementioned could have tended to moderate as the general mobility increased.

Another limitation of this study is that the results only capture between-region dispersion in anthropometric and socioeconomic indicators. Provincial or even municipal (e.g. urban vs. rural) variations are not accounted for due to the characteristics of the data utilized. Thus it is important to acknowledge that regional data most probably mask differences at lower geographical levels. This issue has additional implications in favor of the arguments above developed. For instance, migrants from Andalusia (South Spain) to other regions (mainly to Catalonia) mainly came from the Eastern provinces (Jaen, Córdoba, Granada and Almeria) which were the poorest and probably the shortest on average. This would have moderated the effects of potential height transfers between regions.

The anthropometric patterns depicted in this work cannot be dissociated from the socioeconomic disparities among Spanish regions. However, it is apparent that poor regions caught up in terms of height and robustness more successfully than in economic terms. This seems to us relevant given the absence of specific policies aimed at correcting socioeconomic disparities across the country until the arrival of democracy in the late 1970s; (García-Ballesteros, 1990). As an illustration, poor regions decreased in relative importance to the national GDP over the period analyzed here (Carreras, 1990). Actually, although GDP remained significant as an explanatory factor of height differences in Spain, its strength and significance diminished among cohorts born after the 1950s. Meaningfully, GDP (as a proxy of economic conditions) and m_0 (as a proxy of sanitary conditions) explained nearly 80% of height differences across regions among cohorts born from 1934–38, whereas this decreased at nearly 60% among cohorts born 1969–73. As for the explanatory capacity of GDP and m_0 on BMI and RI differences, this was negligible over the whole period analyzed.

Some discrepancies between height and robustness have been found that are worth comment. Southern regions were invariably poor, short and less robust than average. In

contrast, the robust North-Eastern arch of regions was to some extent independent of economic performance. In other words, high robustness scores were shared by economically developed and underdeveloped regions. Moreover, among northern Spaniards, both relatively tall (e.g., Basque) and relatively short populations (i.e., Galician) are found, but all populations were significantly more robust on average than southern Spaniards. This implies that regions such as Galicia and Castille-Leon were not as disadvantaged as would have been concluded based on an analysis of height alone.

Northern robustness was most likely associated with a better provision and/or easier access to high protein and caloric foodstuffs such as meat and milk. For instance, in 1910–12, the area of robust regions very much coincided with cheaper meat and dairy products among the Spanish provinces (Nicolau and Pujol, 2006). These authors concluded that these patterns were indicative of actual consumption and that Northern provinces generally had easier access to high protein and caloric foodstuffs than inner and southern provinces. Along with Simpson (1995), we hypothesize that meat and dairy products remained rare in these areas until well into the second half of the 20th century. This supposition has several explanations, none of which are mutually exclusive: the historical agricultural specialization by region, the physical constraints to the development of mixed agrarian systems, the limited demand from urban markets and the poor market integration of the country (Simpson, 1995). Furthermore, an estimated food cost index adjusted by wages among twelve Spanish provinces in different regions uncovered systematically higher costs for a set of basic foodstuffs in the southern and inner provinces (Ballesteros, 1997).

The Canary Islands also exemplify an unexpected relationship between height and other developmental indicators as well as composite anthropometric indicators. Any hypothetical environmental (i.e., socioeconomic and/or epidemiologic) advantage attributed to this region in light of its tallness should be questioned in light of robustness outcomes. Males from the Canary Islands were tall but not robust, leading us to think about more than just environmental conditions in explaining their above-average height (e.g., ethnic origins; Hooton, 1925). Furthermore, infant mortality for the Canary Islands was among the highest in Spain at the beginning of the 20th century, and therefore height cannot easily be related to a low exposure to morbidity.

References

- Akachi Y, Canning D. The height of women in Sub-saharan Africa: the role for health, nutrition, and income in childhood. *Annals of Human Biology*. 2007; 34:397–410. [PubMed: 17620149]
- Alcaide, J. *Evolución económica de las regiones y provincias españolas en el siglo XX*. BBVA; Bilbao: 2003.
- Alter G. Height, Frailty, and the Standard of Living: Modeling the Effects of Diet and Disease on Declining Mortality and Increasing Height. *Population Studies*. 2004; 58(3):265–279. [PubMed: 15513283]
- Arcaleni E. Secular trend and regional differences in the stature of Italians, 1854–1980. *Economics and Human Biology*. 2006; 4:24–38. [PubMed: 16051532]
- Ballesteros E. Una estimación del coste de la vida en España, 1861–1936. *Revista de Historia Económica*. 1997; 15(2):363–395.
- Bernardi F, Requena M. La caída de la fecundidad y el déficit de natalidad en España. *Revista Española de Sociología*. 2003; (3):29–49.

- Bhattacharya K, Bharati P, Gupta R, Basu A. A study on diet and nutritional anthropometry of the population of Mirpur, District Midnapore, West Bengal. *Collgm Antropolgm*. 1981; 5:51–58.
- Blanes, A. La mortalidad en la España del siglo XX. Análisis demográfico y territorial. Bellaterra: Universitat Autònoma de Barcelona; 2007.
- Bogin, B. Patterns of Human Growth. Cambridge University Press; Cambridge: 1988.
- Bozzoli C, Deaton A, Quintana-Domeque C. Adult height and childhood disease. *Demography*. 2009; 46(4):647–669. [PubMed: 20084823]
- Cabré, A. El sistema català de reproducció. Barcelona: Proa; 1999.
- Cámara, AD. Niveles de vida en el medio rural de Andalucía Oriental. Granada: Universidad de Granada; 2007. p. 1750-1950.
- Cardelús J, Solana M. Opcions individuals i pautes col·lectives: mobilitat i poblament a Espanya a la segona meitat del segle XX. *Documents d'anàlisi geogràfica*. 2003; 42:37–70.
- Carreras, A. Pautas regionales de la industrialización española (siglos XIX y XX). Ariel; Barcelona: 1990. Fuentes y datos para el análisis regional de la industrialización española, in Jordi Nadal and Albert Carreras (dirs); p. 3-20.
- Carreras, A.; Prados de la Escosura, L.; Rosés, JR. Renta y riqueza. In: Carreras, A.; Tafunell, X., editors. *Estadísticas Históricas de España Siglos XIX y XX*. second. Fundación BBVA; Madrid: 2005. p. 1298-1376.
- Cleveland, TC. Rock solid: African laborers on the diamond mines of the Companhia de Diamantes de Angola (Diamang). University of Michigan; 2011. p. 1917-1975.
- Collantes F, Pinilla V, Sáez LA, Silvestre J. Reducing Depopulation in Rural Spain: The Impact of Immigration. *Population, Space and Place*. 2013; 1002:psp.1797
- Courtial A, Rickard IJ, Lummaa V, Prentice AM, Fulford AJC, Stearns SC. The Demographic Transition Influences Variance in Fitness and Selection on Height and BMI in Rural Gambia. *Current Biology*. 2013; 23(1):884–889. [PubMed: 23623548]
- Cussó X. El estado nutritivo de la población española, 1900–1970. Análisis de las necesidades y disponibilidades de nutrientes. *Historia Agraria*. 2005; 36:329–358.
- Danubio ME, Amicone E, Vargiu R. Height and BMI of Italian immigrants to the USA, 1908–1970. *Economics and Human Biology*. 2005; 3:33–43. [PubMed: 15722261]
- Escudero A, Simón H. El bienestar en España: una perspectiva de largo plazo (1850–1991). *Revista de Historia Económica*. 2003; 21(3):525–565.
- Fernández-Cordón, JA. Análisis longitudinal de la fecundidad en España. In: Olano, A., editor. *Tendencias demográficas y planificación económica*. Madrid: Ministerio de Economía y Hacienda; 1986. p. 49-75.
- Floud, R.; Fogel, RW.; Harris, B.; Chul-Hong, S. The changing body Health, Nutrition and Human Development in the Western World since 1700. Cambridge University Press; Cambridge: 2011.
- Fogel RW, Costa DL. A theory of technophysio evolution, with some implications for forecasting population, health care costs, and pension costs. *Demography*. 1997; 34(1):49–66. [PubMed: 9074831]
- García-Barbancho A, Delgado-Cabeza M. Los movimientos migratorios interregionales en España desde 1960. *Papeles de Economía Española*. 1988; 34:241–266.
- García-Ballesteros A. Desequilibrios interterritoriales en la España de las autonomías. *Boletín de la Asociación de Geógrafos Españoles*. 1990; 11:1–14.
- Gómez-Mendoza A, Pérez Moreda V. Estatura y nivel de vida en la España del primer tercio del siglo XX. *Moneda y Crédito*. 1985; 174:29–64.
- Gómez-Redondo, R. La mortalidad infantil española en el siglo XX. C.I.S.-Siglo XXI; Madrid: 1992.
- Gørgens T, Meng X, Vaithianathan R. Stunting and selection effects of famine: A case study of the Great Chinese Famine. *Journal of Development Economics*. 2012; 97(1):99–111.
- Guillén-Rodríguez M. La estadística de Reemplazo y Reclutamiento de los Ejércitos. *Estadística Española*. 1959; (3):71–75.
- Hatton TJ, Bray BE. Long run trends in the heights of European men, 19th–20th centuries. *Economics and Human Biology*. 2010; 8:405–413. [PubMed: 20399715]

- Hoyos-Sainz, L. Antropodemografía española. Regiones y razas. Real Sociedad Geográfica; Madrid: 1942.
- Hooton, EA. The Ancient Inhabitants of the Canary Islands. Harvard University Peabody Museum; Harvard: 1925.
- IHDI (International Human Development indicators). Online <http://hdrstats.undp.org/en/countries/profiles/ESP.html> [10/01/2013]
- INE (Instituto Nacional de Estadística). Online. Series of vital statistics from 1941 and historical vital registers at INEbase/Historia [10/01/2013].
- Komlos J, Baten J. Recent Research in Anthropometric History. *Social Science History*. 2004; 28(2) Special Issue.
- Livi-Bacci, M. A Concise History of World Population. Cambridge, Mass., USA: Blackwell Publishers; 1992.
- Martínez-Carrión JM. Estaturas, desigualdad regional y desarrollo económico en Italia y España durante el siglo XX. *Mediterráneo Económico*. 2005; 7
- Martínez-Carrión JM. La Historia Antropométrica y la Historiografía Iberoamericana. 2009; 47 Monograph in *Historia Agraria*
- Martínez-Carrión JM. La talla de los europeos, 1700–2000: ciclos, crecimiento y desigualdad. *Investigaciones de Historia Económica*. 2012; 8:176–187.
- Mascie-Taylor, CGN. The interaction between geographical and social mobility. In: Boyce, AJ., editor. *Migration and Mobility, Biosocial Aspects of Human Movement; Symposia of the Society for the Study of Human Biology*, 23; London and Philadelphia: Taylor & Francis; 1984. p. 161–178.
- Moorad JA. A demographic transition altered the strength of selection for fitness and age-specific survival and fertility in a 19th century American population. *Evolution*. 2013; 67(6):1622–1634. [PubMed: 23730757]
- Nicolau, R. Población, salud y actividad. In: Carreras, A.; Tafunell, X.; Xavier, editors. *Estadísticas Históricas de España Siglos XIX y XX*. Second. Fundación BBVA; 2005. p. 79–154.
- Nicolau R, Pujol J. Variaciones regionales de los precios de consumo y de las dietas en España, en los inicios de la transición demográfica. *Revista de Historia Económica*. *Journal of Iberian and Latin American Economic History*. 2006; 24(3):521–554.
- Pandey AK. Anthropometry of Female Onges of Little Andaman. *Anthropologist*. 2006; 8(2):99–102.
- Peracchi F, Arcaleni E. Early-life environment, height and BMI of young men in Italy,” *Economics and Human Biology*. *Economics and Human Biology*. 2011; 9:251–264. [PubMed: 21596628]
- Quiroga, G. Height evolution in Spain, 1893–1954. An analysis by regions and professions. In: Komlos, J.; Baten, J., editors. *The biological standard of living in comparative perspective*. Franz Steiner; Stuttgart: 1998. p. 359–383.
- Quiroga G. Estatura, diferencias regionales y sociales y niveles de vida en España (1893–1954). *Revista de Historia Económica*. 2001; 19(1):175–200.
- Ramiro-Fariñas D, Sanz-Gimeno A. Structural Changes in Childhood Mortality in Spain, 1860–1990. *International Journal of Population Geography*. 2000; 6:61–82.
- Reher DS. In search of the ‘urban penalty’: exploring urban and rural mortality patterns in Spain during the demographic transition. *International Journal of Population Geography*. 2001; 7:105–127.
- Rodríguez V, Egea C, Nieto JA. Return migration in Andalusia, Spain. *International Journal of Population Geography*. 2002; 8:233–254.
- Salvatore R. Stature, Nutrition, and Regional Convergence: The Argentine Northwest in the First Half of the Twentieth Century. *Social Science History*. 2004; 28(2):297–324.
- Silventoinen K. Determinants of Variation in Adult Body Height. *Journal of Biosocial Science*. 2003; 35:263–85. [PubMed: 12664962]
- Simpson, J. Spanish agriculture: the long siesta, 1765–1965. Cambridge University Press; Cambridge: 1995.

- Spijker J, Cámara AD, Blanes A. The health transition and biological living standards: adult height and mortality in 20th-century Spain. *Economics and Human Biology*. 2012; 10(3):276–288. [PubMed: 21924964]
- Steckel RH. Heights and Human Welfare: Recent Developments and New Directions. *Explorations in Economic History*. 2009; 46(1):1–23.
- Steckel RH. Biological Measures of Economic History. *Annual Review of Economics*. 2013; 5(1): 401–23.
- Szklarska A, Lipowicz A, Lopuszanska M, Bielicki T, Koziel S. Biological condition of adult migrants and nonmigrants in Wrocław, Poland. *American Journal of Human Biology*. 2008; 20:139–145. [PubMed: 17990325]
- Tassenaar, V. A Study Based on Anthropometric Data. University of Groningen; Groningen: 1995. Regional Differences in Standard of Living in the Netherlands, 1800–1875.
- Waller HT. Height, Weight and Mortality: The Norwegian Experience. *Acta Medica Scandinavica*. 1984; Supplementum 679:1–51. [PubMed: 6585126]
- Wolanski N. Secular trend, secular changes, or long-term adaptational fluctuations? *Acta Medica Auxologica*. 1985; 17(1):7–19.

Figure 1.

Average cohort male height (cm) over the 20th century in a sample of Western countries.

Source: Hatton and Bray, 2010

Figure 2.

Frequency distributions (percent) of height, weight and chest circumference by birth cohort for Spanish males born between 1934–68.

Source: Spanish Yearbooks, Military Statistics

Figure 3. Current administrative division of Spain (left) and anthropo-demographic regions used in this work (right).

Figure 4.

Scatter plots showing the association between GDP and infant mortality by region in Spain for three cohort groups.

Note. This figure plots the log transformation of GDP and m_0 to present an overview of the data and to illustrate the relationships between all three cohort groups.

Figure 5.

Cohort height, cohort body mass index and cohort robustness index across Spanish regions for Spanish males born from 1934–68.

Source: Calculated from the military statistics of Spanish Yearbooks.

Note. A decrease in RI indicates an increase robustness (colors on the map were set to point in the same direction, with darker indicating taller and more robust).

Figure 6.

Trends in cohort height (cm) and cohort robustness (units) in selected Spanish regions.

Source: Calculated from the Military Statistics of Spanish Yearbooks.

Figure 7. Variation coefficients of height, BMI, RI, m_0 and *per capita* GDP across regions, Spain, 1934–73.
Source: Calculated from the military statistics of Spanish Yearbooks.

Table 1

Correlation matrix of the indicators involved in this work for cohort groups 1934–38, 1949–53, and 1969–73.

1934–38						
	HEIGHT	WEIGHT	CHEST	BMI	RI	GDP
HEIGHT	1	.677*	.818**	0.028	–0.295	.846**
WEIGHT		1	.947**	.712*	–.900**	0.567
CHEST			1	0.517	–.769**	.738**
BMI				1	–.900**	0.026
RI					1	–0.263
GDP						1
M0						
	HEIGHT	WEIGHT	CHEST	BMI	RI	GDP
HEIGHT	1	.627*	.755**	–0.044	–0.191	.897**
WEIGHT		1	.884**	.734*	–.873**	.747**
CHEST			1	0.495	–.716*	.866**
BMI				1	–.949**	0.211
RI					1	–0.438
GDP						1
M0						
	HEIGHT	WEIGHT	CHEST	BMI	RI	GDP
HEIGHT	1	.627*	.755**	–0.044	–0.191	.897**
WEIGHT		1	.884**	.734*	–.873**	.747**
CHEST			1	0.495	–.716*	.866**
BMI				1	–.949**	0.211
RI					1	–0.438
GDP						1
M0						
	HEIGHT	WEIGHT	CHEST	BMI	RI	GDP
HEIGHT	1	0.376		–0.521		.749**
WEIGHT		1		0.326		0.378
CHEST			1			–0.106
BMI				1		–0.189
RI					1	–.822**
GDP						1
M0						

Source. The authors' calculations from the data sources described in this section of the paper.
Note: Asterisks indicate two-tailed significance at the 0.01 level (**) and the 0.05 level (*).

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Table 2
Per capita GDP (in current values; million pesetas) and infant mortality rates (per thousand) in Spanish regions.

Region	GDP						m0						Index numbers																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
	1935-40			1950-55			1970-75			1934-38			1949-53			1969-73			1930			1950			1970			1934-38			1949-53			1969-73																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																

Source: Author's adaptation from data in Alcaide (2003) and Gómez-Redondo (1992).

Table 3
OLS regression coefficients and R². Height, BMI and RI regressed on GDP and infant mortality.

1934–38			
	On height	On BMI	On RI
logGDP	6.473**	-1.87	2.92
logm0	-5.14	-4.11	14.42
R ²	0.78	0.26	0.27
1949–53			
	On height	On BMI	On RI
logGDP	6.617***	0	-3.3
logm0	-2.33	-1.32	4.06
R ²	0.83	0.07	0.21
1969–73			
	On height	On BMI	On RI
logGDP	5.035*	0.99	
logm0	1	2.38	
R ²	0.58	0.3	

Note: significant at 99% (***), 95% (**) and 90% (*).