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Anthropometric Geography Applied to the Analysis of Socio-economic 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 socio-economic 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 socio-economic 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 in 1934–1973 who were recorded in the Spanish military statistics. This information is interpreted in light of region-level data on gross domestic product 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 north-eastern 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 socio-economic disparities, although the former lessened over time to a greater extent than the latter. Interestingly, the various anthropometric indicators utilised here do not point to the same conclusions. There have been some discrepancies found between height and robustness patterns that moderate the statements from the analysis of cohort height alone regarding the level and evolution of living conditions across Spanish regions.

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Keywords: height; robustness; anthropometric geography; spatial disparities; cohort trends; living conditions

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 socio-economic and epidemiological

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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 period than social and historical changes. For instance, in the past century, covering just three to five 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 & 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 intergenerational 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 because of living conditions (Alter, 2004; Bozzoli *et al.*, 2009). Although 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, as both 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 (Waaler, 1984).

The relationship between the patterns of human growth and the environment is 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 (see Fogel & Costa, 1997; Floud *et al.*, 2011, for an updated view and review articles with citation of early works in Steckel, 2009, 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 socio-economic 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 socio-economic processes have had on populations over time (e.g. Komlos & 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 gross domestic product (GDP) (e.g. Akachi & Canning, 2007; Bozzoli *et al.*, 2009; Peracchi and Arcaleni, 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 performed, the time span was very limited and therefore the possibility to analyse 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 labour

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conditions of some 20th-century populations (Cleveland, 2011).

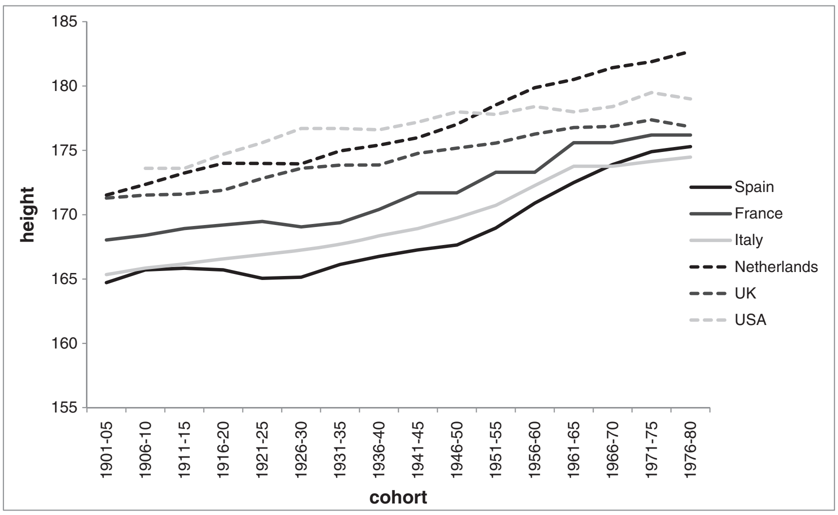
In this work, we analyse regional anthropometric data from Spanish male cohorts born in 1934–1973 to obtain further insights on the evolution of socio-economic disparities and their effects on the biological status of the population. To do this, changes in the anthropometric geography of Spain over time are examined through continuous series of adult cohort height, BMI, and RI for Spanish regions. The results are discussed in light of socio-economic processes in the mid-20th century.

Spain stands out among current affluent Western societies for its rapid and intense progress towards high development levels during the 20th century. Diverse indicators reflect the magnitude of socio-economic changes in this country over that period (Ramiro-Fariñas & Sanz-Gimeno, 2000). Life expectancy at the turn of the 20th century was barely 35 years[1]; in 1950, it had risen to 62 years, and in 2000, it was approximately 79 years, 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 female Spaniards were approximately 6 cm taller than those born during the first decades of the 20th century (Spijker *et al.*, 2012), one of the steepest increases documented among Western European countries (Hatton & Bray, 2010) (Fig. 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 (Cabré, 1999) and 1.25 in 2001(Bernardi & 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; Fernández-Cordón, 1986) to 2.4 (1946–1950 cohort; Cabré, 1999) and 1.76 (1956–1960 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 1934–1973).

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 & Simón, 2003), whereas it was 0.839 in 2000 (UNDP online database).[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.



Source: Hatton and Bray, 2010

Figure 1. Average cohort male height (cm) over the 20th century in a sample of Western countries.

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, Martínez-Carrión (2005) analysed 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 socio-economic 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 with 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 three main contributions. First, it demonstrates the ability of anthropometric geography to shed light on socio-economic disparities. Second, it illustrates how socio-economic disparities within a country can be analysed from the spatial (i.e. inter-regional) and 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: BMI and RI. Discrepancies between these indicators are of particular interest because 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 summarise individual data obtained from men 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 years 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 centimetres), weight (in kilogrammes), and chest circumference (CC, in centimetres). 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 very low. Although some departures from normal distributions are observed, the data seem to be adequate for the purposes of this work (Fig. 2).

The BMI and the RI are two summary measures of the average physique of a population. BMI is the ratio between the mean weight (in kilogrammes) divided by the square of the mean height (in metres). The categories commonly accepted for this index are *underweight* ($<18.5\,kg/m^2$), *normal weight* (18.5–$24.9\,kg/m^2$), *overweight* (25.0–$29.9\,kg/m^2$), and *obese* ($>30.0\,kg/m^2$). RI is determined by

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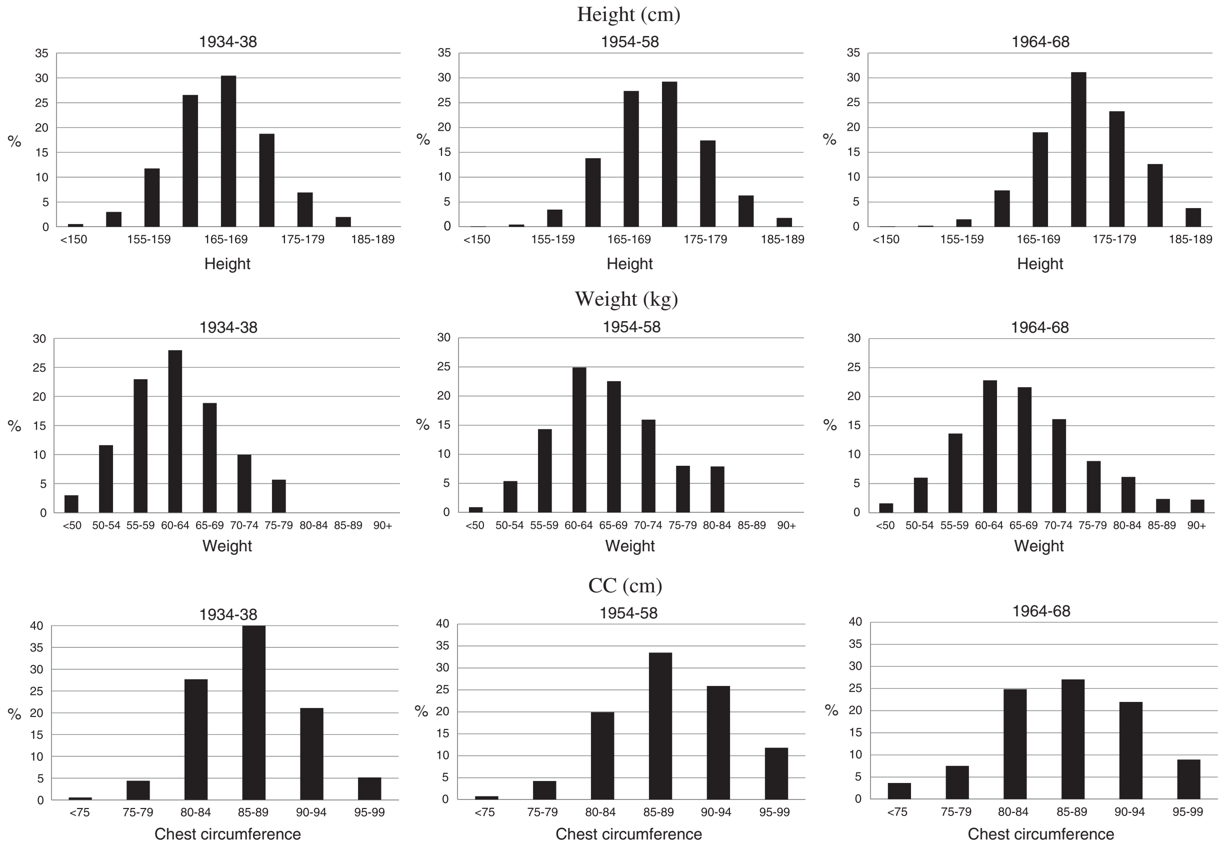

Source: Spanish Yearbooks, Military Statistics

Figure 2. Frequency distributions (%) of height, weight, and chest circumference by birth cohort for Spanish men born between 1934 and 1968.

subtracting the sum of weight (in kg) and 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 positions.[5] Subsequently, anthropological and developmental studies also made use of this measure because of its straightforward nature and its relationship to economic circumstances (e.g. 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), and >35 (poor).[6]

The mean values of height, BMI, and RI were computed for 5-year cohort groups.[7] These means were compared with 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 analysed 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

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Table 1. Correlation matrix of the indicators involved in this work for cohort groups 1934–1938, 1949–1953, and 1969–1973.

	Height	Weight	Chest	BMI	RI	GDP	m_0
				1934–1938			
Height	1	0.677*	0.818**	0.028	−0.295	0.846**	−0.767**
Weight	0.677*	1	0.947**	0.712*	−0.900**	0.567	−0.733*
Chest	0.818**	0.947**	1	0.517	−0.769**	0.738**	−0.764**
BMI	0.028	0.712*	0.517	1	−0.900**	0.026	−0.37
RI	−0.295	−0.900**	−0.769**	−0.900**	1	−0.263	0.495
GDP	0.846**	0.567	0.738**	0.026	−0.263	1	−0.704*
m_0	−0.767**	−0.733*	−0.764**	−0.37	0.495	−0.704*	1
				1949–1953			
Height	1	0.627*	0.755**	−0.044	−0.191	0.897**	−0.740**
Weight	0.627*	1	0.884**	0.734*	−0.873**	0.747**	−0.634*
Chest	0.755**	0.884**	1	0.495	−0.716*	0.866**	−0.752**
BMI	−0.044	0.734*	0.495	1	−0.949**	0.211	−0.242
RI	−0.191	−0.873**	−0.716*	−0.949**	1	−0.438	0.399
GDP	0.897**	0.747**	0.866**	0.211	−0.438	1	−0.727*
m_0	−0.740**	−0.634*	−0.752**	−0.242	0.399	−0.727*	1
				1969–1973			
Height	1	0.376		−0.521		0.749**	−0.631*
Weight	0.376	1		0.326		0.378	−0.106
Chest							
BMI	−0.521	0.326		1		−0.189	0.453
RI							
GDP	0.749**	0.378		−0.189		1	−0.822**
m_0	−0.631*	−0.106		0.453		−0.822**	1

Source: Authors' calculations from the data sources described in the Data and Methods section.
BMI, body mass index; GDP, gross domestic product; RI, robustness index.
**Two-tailed significance at the 0.01 level.
*Two-tailed significance at the 0.05 level.

allows us to capture significant variations in mean BMI and RI between cohort groups as well as regional disparities. For instance, by keeping weight constant at 60 kg, a 2-cm change in height (e.g. from 166 to 168 cm) results in a decrease in BMI from 21.77 to 21.25. By keeping weight and CC constant at 60 kg and 80 cm, respectively, a 2-cm change in stature (from 166 to 168) 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 organisation 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 this paper. The so-called anthropo-demographic regions utilised in the source roughly coincide with the current administrative structure of Spain (Fig. 3).[8]

Gross Domestic Product and Infant Mortality Data

These data were collected for three cohort groups: 1934–1938, 1949–1953, and 1969–1973 (i.e. per-capita

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GDP and m_0 correspond to the birth years of the conscripts).

Gross domestic product 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 5 years, averages between the two dates were used when necessary. For instance, the GDP associated with the 1934–1938 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 anthropo-demographic regions.

Infant mortality rates were drawn from Gómez-Redondo (1992). As her data were originally provided by provinces, they had to be fitted to the regional setting of the military statistics. As provinces within any region differ in size, population, and socio-economic characteristics, the 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 database). 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 harmonisation 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 north-eastern regions consistently ranked at the top. For the most part, infant mortality was also lower in those regions. Actually, GDP and m_0 maintained a strong linear relationship throughout the period analysed here, with few exceptions (Fig. 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 urbanisation 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 in 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 ordinary least squares regression in which both GDP and m_0 were transformed into their natural logarithms.

RESULTS

The average stature of Spanish men increased approximately 9 cm (or 5.4%) from the 1934 cohort to the 1973 cohort. The average weight increased from 62 to 69.4 kg (or 11.9%), and the average CC increased from 87 to 89 cm (or 2.3%) for the 1964–1968 cohort. BMI and RI do not exhibit a uniform trend over time because of the changing relationship between their components. BMI rose among the 1934–1948 cohorts and decreased

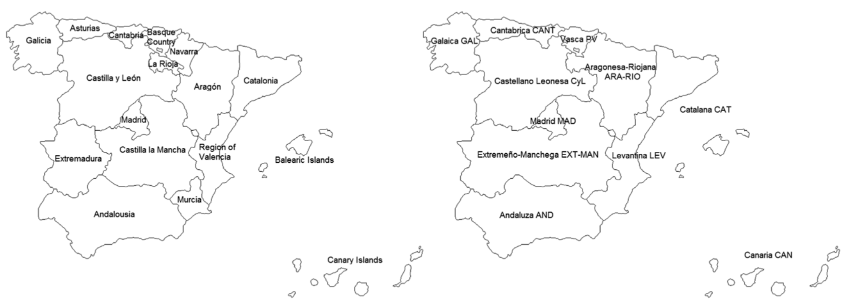

Figure 3. Current administrative division of Spain (left) and anthropo-demographic regions used in this work (right).

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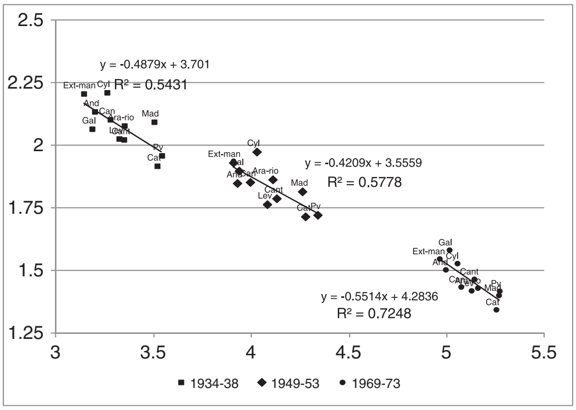
Table 2. Per-capita GDP (in current values; million *pesetas*) and infant mortality rates (per thousand) in Spanish regions.

	GDP			m_0			Index numbers											
							GDP						m_0					
Region	1935–1940	1950–1955	1970–1975	1934–1938	1949–1953	1969–1973	1930		1950		1970		1934–1938		1949–1953		1969–1973	
AND	1,576	8,448	98,174	136.81	70.75	31.96	76.4	9	72.5	9	72.5	10	105.7	9	98.3	6	111.6	8
ARA-RIO	2,236	12,824	143,168	120.1	73.18	27.01	112	4	110.03	5	108.9	4	92.8	6	101.7	8	94.3	5
CAN	1,893	9,829	117,661	127.16	71.45	27.28	92.1	7	83.2	8	85.2	7	98.2	8	99.3	7	95.2	6
CANT	2,224	13,431	137,402	105.69	61.49	29.3	100.45	5	114.3	4	105.4	5	81.7	3	85.5	4	102.3	7
CAT	3,292	18,840	177,980	82.92	52.06	22.12	148.75	2	138.9	3	133.2	2	64.1	1	72.4	1	77.2	1
CyL	1,823	10,630	112,567	163.09	94.48	33.85	89.7	8	92.6	6	83.5	8	126	11	131.3	11	118.2	9
EXT-MAN	1,386	8,066	91,335	161.24	85.43	35.32	66.55	11	66.9	11	64.8	11	124.6	10	118.7	10	123.3	10
GAL	1,529	8,625	102,549	116.63	79.27	38.32	74.7	10	72.1	10	78.8	9	90.1	5	110.2	9	133.8	11
LEV	2,102	12,016	132,944	106.58	58.22	26.34	92.4	6	89.95	7	91.75	6	82.3	4	80.9	3	91.9	4
MAD	3,176	18,168	183,572	124.37	65.53	25.24	145.7	3	148.3	2	132.9	3	96.1	7	91.1	5	88.1	2
PV	3,473	21,761	184,973	91.23	52.81	26.26	161.2	1	181.6	1	142	1	70.5	2	73.4	2	91.6	3

Source: Author's adaptation from data in Alcaide (2003) and Gómez-Redondo (1992).
GDP, gross domestic product. m_0, infant mortality rate.



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 4. Scatter plots showing the association between gross domestic product (GDP) and infant mortality by region in Spain for three cohort groups.

among subsequent cohort groups because of the strong increase in mean cohort height. Robustness increased among the 1934–1948 cohorts because of limited progress in stature and proportionally higher increases in weight and CC. This trend was reversed among cohorts born after 1949, because of 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 (Fig. 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) (Fig. 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 north-eastern 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 (Fig. 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 (e.g. 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*, respectively[9]). 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 urbanisation.

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 (Fig. 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 non-existent ability for BMI and RI, likely owing 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 analysed 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 socio-economic disparities captured by GDP and infant mortality.

In our view, the strong anthropometric disparities that were initially observed across regions

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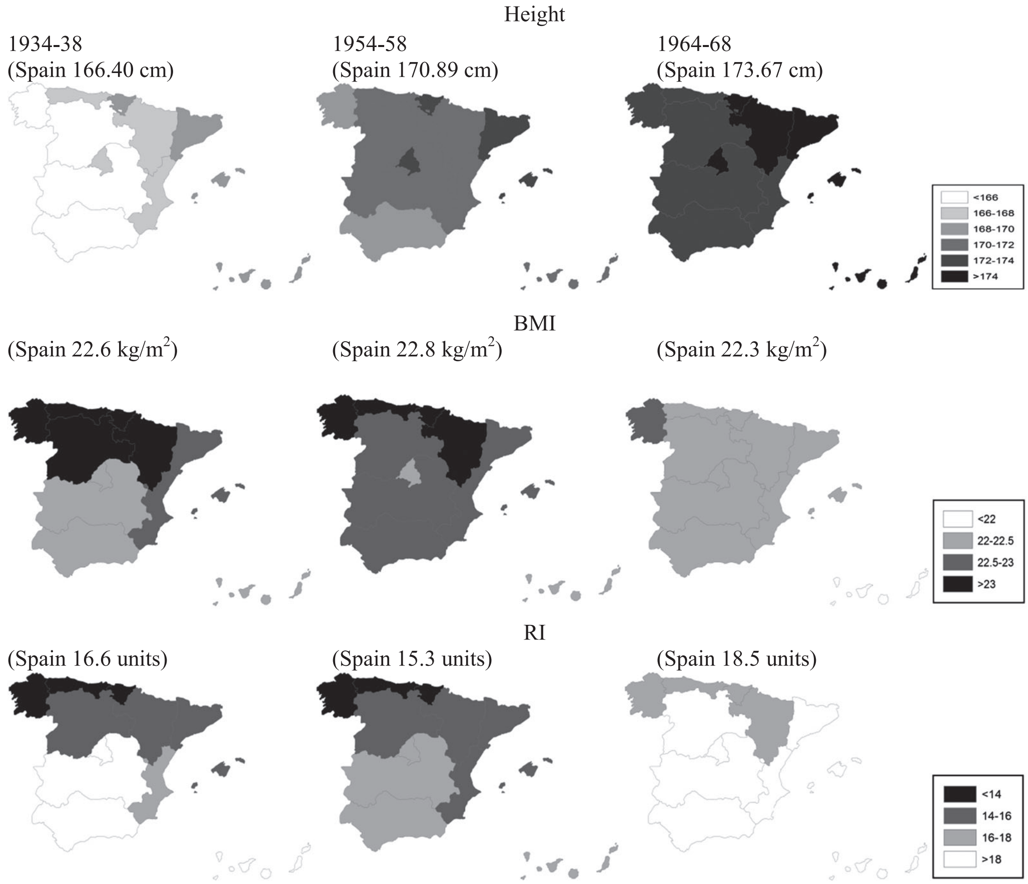
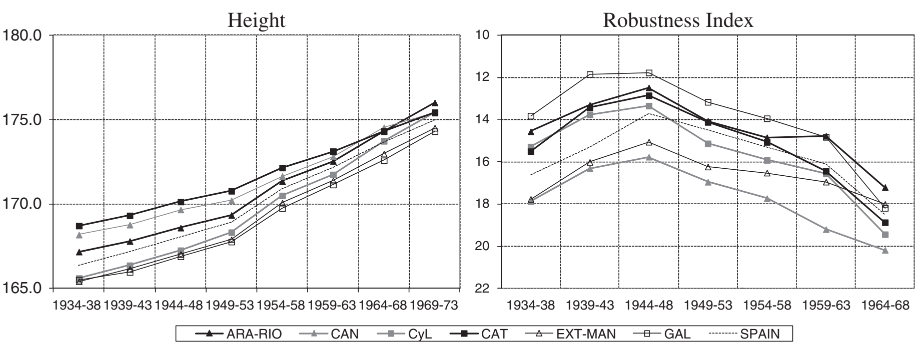


Source: Calculated from the military statistics of Spanish Yearbooks.
Note. A decrease in RI indicates an increase robustness (colors on the map were set to point in the same direction, with darker indicating taller and more robust).

Figure 5. Cohort height, cohort body mass index (BMI), and cohort robustness index (RI) across Spanish regions for Spanish men born from 1934 to 1968. Q1



Source: Calculated from the Military Statistics of Spanish Yearbooks.

Figure 6. Trends in cohort height (cm) and cohort robustness (units) in selected Spanish 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 & Pérez-Moreda, 1985). To be sure, Spanish regions appeared in a very similar ordinal ranking (to that observed among cohorts 1934–1938) of height among cohorts born in 1875–1934 (Quiroga, 1998, 2001). This ordinal

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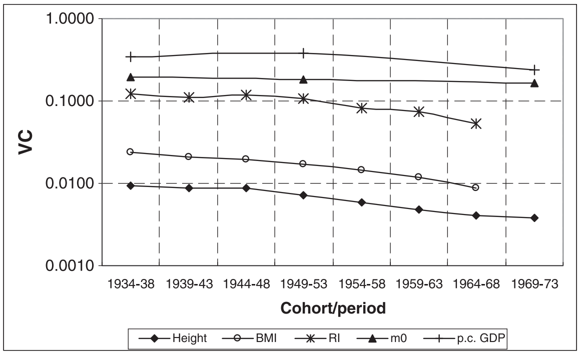

Source: Calculated from the military statistics of Spanish Yearbooks.

Figure 7. Variation coefficients (VC) of height, body mass index (BMI), robustness index (RI), m_0, and per-capita gross domestic product (GDP) across regions in Spain, 1934–1973.

Table 3. Ordinary least squares regression coefficients and R^2.

	On height	On BMI	On RI
	1934–1938		
logGDP	6.473**	−1.87	2.92
logm_0	−5.14	−4.11	14.42
R^2	0.78	0.26	0.27
	1949–1953		
logGDP	6.617***	0	−3.3
logm_0	−2.33	−1.32	4.06
R^2	0.83	0.07	0.21
	1969–1973		
logGDP	5.035*	0.99	
logm_0	1	2.38	
R^2	0.58	0.3	

Height, BMI, and RI regressed on GDP and infant mortality.
BMI, body mass index; GDP, gross domestic product; RI, robustness index.
***Significant at 99%.
**Significant at 95%.
*Significant at 90%.

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 rest of positions also remained largely stable.

All three anthropometric indicators, height, BMI, and RI converged across regions over the period analysed 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 worse-off populations. These populations would respond more positively to improvements in environmental conditions (Wolanski, 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 because 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 & 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 hypothesised notwithstanding.

If migrants were systematically taller than non-migrants and/or taller than the natives at their destination, this 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, such as the coexistence of tallness, low robustness, and high infant mortality in Madrid

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among the earlier cohorts analysed. In Madrid, selective immigration might have produced high mean heights without a significant improvement of living standards. The latter is suggested by low BMI and RI in Madrid among the earlier cohorts analysed. Other economically developed regions could experience this, but in such cases, 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 uni-provincial 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 socio-economic 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 to 1970 (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 & Solana, 2003), and therefore, the potential selection forces mentioned earlier 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 socio-economic indicators. Provincial or even municipal (e.g. urban vs rural) variations are not accounted for because of the characteristics of the data utilised. Thus, it is important to acknowledge that regional data most probably mask differences at lower geographical levels. This issue has additional implications in favour of the arguments developed earlier. 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 socio-economic 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 socio-economic 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 analysed 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 to 1938, whereas this decreased at nearly 60% among cohorts born in 1969–1973. As for the explanatory capacity of GDP and m_0 on BMI and RI differences, this was negligible over the whole period analysed.

Some discrepancies between height and robustness that are worth comment have been found. 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 on the basis of 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 1910–1912, the area of robust regions very much coincided with cheaper meat and dairy products among the Spanish provinces (Nicolau & 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

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southern provinces. Along with Simpson (1995), we hypothesise 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 specialisation 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 12 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. socio-economic and/or epidemiologic) advantage attributed to this region in light of its tallness should be questioned in light of robustness outcomes. Men 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.

NOTES

(1) In 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, 1990).

(2) Fertility 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 (1901–1904 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 in 1946–1950 gave birth to 2.26 children on average (the figure for Spain was 2.45) and 1.97 (1.76), respectively, among women born in 1956–1960 (Cabré, 1999; Nicolau, 2005).

(3) HDI 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.

(4) The 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 percentage of missing cases reported in the sources. This compels us to omit the results on thorax circumference and RI for the last cohort group analysed in this work (1969–1973). Thus, the cohort group 1964–1968 was chosen to close the map series.

(5) This 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 utilised it at the beginning of the 20th century.

(6) The meaning of these categories was adapted by the Spanish army as follows: *very strong*, *strong*, *good*, *intermediate*, *weak*, *very weak*, and *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 women (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 men 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.

(7) The average of the 1955–1959 enlistments (the 1934–1938 cohort) is derived from 3 years of data because regional data were not provided for 1956 and 1957. The average of the 1970–1974 enlistments (the 1949–1953 cohort) is a 3-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.

(8) The data are provided in anthropo-demographic 'zones' and 'regions' (Hoyos-Sainz, 1942). Regions are more convenient for our purposes because 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 anthropo-demographic

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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* (Andalucia). Note that Hoyos' criterion results in some socio-economic 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*.

(9) The latter is mainly due to the very low infant mortality rates in the Balearic Islands, 72.3 per thousand in 1934–1938 (Gómez-Redondo, 1992).

(10) Cámara (2007: 300) reported that the average height of 30 migrants from the Andalusian town of Santafe (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 Santafe 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).

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