Association of height and lifespan among men in rural Spain, birth cohorts 1835-1939

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Abstract: This article analyses the relationship between male height and age at death and its evolution over time among adults born between 1835 and 1939 in fourteen villages in north-east rural Spain. A total of 1,488 conscripts who died between 1868 and 2019 have been included in the analysis. The height data have been obtained from conscriptions for military service, and demographic and socioeconomic information of the deceased were obtained from parish archives and censuses. The data were linked according to nominative criteria using family reconstitution methods. The results suggest a positive relationship between height and life span in the long-term. For the birth cohorts of 1835-1869, conscripts with a height of 170 cm or more lived on average 7.6 years longer than conscripts measuring less than 160 cm. This difference in life expectancy disappeared for the birth cohort of 1900-1939 due to a progressive improvement in health and nutrition conditions, benefiting especially the short conscripts.

Keywords: Height, Biological well-being, Later-life outcomes, rural Spain, nineteenth and twentieth centuries

JEL classification: I10, I14, I15, N33, N34

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1. INTRODUCTION

The study of the historical evolution of the living standards of populations is a central theme in the field of economic history (Voth, 2004; Salvatore et al., 2010; Floud et al., 2011, 2014; Komlos and Kelly, 2016). Within a subject as broad as well-being, the study of human body proportions and measurements, especially height, has been successfully consolidated, giving rise to a whole field of knowledge known as anthropometric history (Floud, 2004; Komlos and Baten, 2004; Steckel, 2008, 2019; Komlos, 2009; Komlos and Kelly, 2016; NCD-RisC, 2016, 2020). The height of an individual or a given biological population is the result of a combination of genetic, environmental and socio-economic factors (Eveleth and Tanner, 1990; Silventoinen, 2003; McEvoy and Visscher, 2009; Grasgruber et al., 2014, 2020; Hatton, 2014; NCD-RisC, 2016). In the process of expansion of anthropometric history since the late 1970s, it has undoubtedly contributed to some of the historically important debates, such as that on working-class living standards during the first industrial revolution or the causes of the secular decline in mortality since the mid-19th century (Komlos, 1998, 2009; Komlos and Baten, 2004; Steckel, 2009; 2019; Komlos and Kelly, 2016; Galofré-Vilà, 2018).

As an indicator of net nutritional status, height accounts for the energy input produced by food consumption and the energy expenditure produced by illness, work and environmental conditions since maternal pregnancy, with the circumstances during childhood and adolescence being decisive. In this sense, the variability of growth processes is strongly influenced by health, nutrition and socio-economic factors (Tanner, 1981; Bogin, 2001; NCD-RisC, 2016; Perkins, 2016). Thus, although the human body is capable of deploying compensatory growth mechanisms in adolescence, it has been proven that situations of severe malnutrition caused by an inadequate or insufficient diet can alter the normal process of physical growth, delaying it and affecting the final adult height (Martorell, 2010; Bogin et al., 2018). As result, and after several decades of research, we are able to establish that height is a good indicator to study the biological well-being of the population (Komlos and Baten, 2004; Steckel, 2008, 2019; Komlos, 2009; Salvatore et al., 2010; Floud et al., 2011,; Craig, 2014; Hatton, 2014; Komlos and Kelly, 2016; Galofre-Vilà, 2018).

Height could be conditioned by 'scarring' effects that would condition the sample. On the one hand, there are effects that negatively affect height, such as the diseases experienced by the individuals, which affected their growth and reduced the height attained. On the other hand, if the highest mortality rates occurred among children with the worst living conditions, then the survival of the tallest would be proportionally higher, conditioning the average height of the period (Alter and Riley, 1989; Alter, 2004; Black et al., 2008; Bozzoli et al., 2009). However, for mortality to bias the sample, it would be necessary for the genetically shortest individuals to die. Given that if mortality is a function of living and health conditions rather than genetics, it is living and health conditions that explain the average height outcome in a society (Moradi, 2010). In any case, the scarring effects of mortality continue to be debated (Deaton, 2007; Klasen, 2008; Moradi, 2010). Scarring effects can also affect the relationship between height and age at death through the psychology of individuals. Shorter individuals have lower salaries (Case and Paxson, 2008; Schick and Steckel, 2015) and lower chances of being successful in the marriage market (Hacker, 2008; Manfredini et al., 2013; Sohn, 2015; Marco-Gracia, 2018a; Murasko, 2020). This could lead to a feeling of inferiority that could lead to more self-destructive behaviour, either through alcohol abuse, poor diet or a more dissolute lifestyle, among other possible behaviours (on feeling of inferiority: Dixon and Strano, 1989). However, we have no evidence to justify that the mortality of the individuals in the sample is the result of self-destructive behaviour. In fact, as we will see below, there are no important differences in the causes of death in short and tall individuals. We will return to scarring effects in the discussion section.

In relation to mortality decline, the points of debate are well known (Mckeown, 1976; Szreter, 1988). Improvements in food production and consumption, driven by technological advances, have contributed greatly to the improvement of health in the Western countries since the 19th century (Floud et al., 2011). In addition, most studies have also emphasised the importance of medical advances and public health, especially in the prevention of infectious diseases (Preston and Haines, 1991; Cutler and Miller, 2005). Previously, in a vicious circle, the prevalence of water- and food-borne infectious diseases, such as typhoid fever or gastroenteritis, was enough to restrict the ability to absorb nutrients, affecting children's growth. The improvement of hygienic-sanitary conditions since the end of the 19th century, reflected in a decrease in infant morbidity and mortality, allowed an increase in average height, as attested by various anthropometric studies (Bozzoli et al., 2009; Hatton, 2011; 2014; Peracchi and Arcaleni, 2011; Spijker et al., 2012). Using height data as an indicator of net nutritional status, Fogel (1986) investigated Mckeown's thesis to assess the influence of diet on mortality decline. According to his calculations, between the early 19th century and the late 20th century, improvements in nutrition contributed 40% to the fall in mortality in Britain. Since then, several studies have analysed the complex relationships between height, mortality and life expectancy in different geographical and historical contexts (Schmidt et al., 1995; Alter, 2004; Sear, 2010; Hatton, 2011; Spijker et al., 2012). The aim of this article is to explore this issue in more depth. Therefore, from an anthropometric history approach, this paper studies the relationship between male height and age at death, analysing the influence of height on life expectancy among adults born between 1835 and 1939 in fourteen villages in north-east rural Spain.

Some studies have focused on the relationship between height and the lifespan of adults previously (Fogel, 1994).[1] Waaler (1984) showed that, for Norway, the shortest men had more than 70% probabilities of dying in the following year than the tall individuals, with the exception of the tallest people. He demonstrated the existence of a connection between height and average age at death that was still prevalent in Norway in the 1970s. A similar pattern was found by Costa (2004) with data on soldiers from the American Civil War. Based on European and American data for the years 1860, 1900 and 1950, Baten and Komlos (1998) estimated that every centimetre of height was equivalent to an increase in life expectancy of 1.2 years. Alter, Neven and Oris (2004a) found a positive correlation between life span, height and occupation (as socioeconomic status indicator) in nineteenth century Belgium. Similar results were found in western Scotland (Smith et al., 2000). Recently, Thompson, Quanjer and Murkens (2020) have demonstrated a positive connection between physical growth and life span in the city of Maastricht for individuals born between 1834 and 1843. However, not all studies confirm this positive correlation between height and lifespan. Other authors who have worked with recent data find that short individuals have some health and longevity advantages (Samaras and Elrick, 2002; Samaras, 2012).

None of the cited studies analysing the relationship between height and life span (or life expectancy) are based on longitudinal observations for more than a century. Therefore, the aim of this study is to analyse the determinants of the age of death, paying special attention to the contribution of height and its evolution over time, for those born between 1835 and 1939 (who died between 1868 and 2019) in fourteen rural Spanish villages. For this analysis, first, we studied the determinants of height, and second, we analysed which factors could explain the relationship between height and life span. Height has been

[1] We use the term 'life span' as an indicator of the age at death of an individual or a population.

shown to be strongly correlated with several socio-economic and environmental variables linked to living conditions during childhood and adolescence. Because of this, we use height as a proxy for the living conditions experienced by each individual up to the age of 21. In addition, some social factors, such as wage differences between individuals, could also influence the relationship between height and age at death. Tall individuals tend to have higher wages than short individuals (Case and Paxon, 2008; Schick and Steckel, 2015). Higher wages may have allowed for a more diverse diet, with a higher presence of animal protein. Thus, height is not only a proxy for early life conditions but could be capturing other post-21-years effects.

To carry out this analysis, we used a sample of 1,488 men that includes information on their height at approximately 21 years of age drawn from the military conscription records, in addition to data on their families and their life trajectory. Thus, we have also used life courses extracted from parish archives of baptisms, marriages and deaths for the fourteen villages of the study. This complementary information has allowed us to verify that all men who reached the adult age were called up for conscription. The period of study analyzed, birth cohorts of 1835-1939, partly coincided with the beginnings of Spanish economic and social modernisation process, reflected in a gradual change in the productive structure and the advance of urbanisation (Nicoalu, 2005; Maluquer de Motes, 2014; Pérez Moreda et al., 2015; Prados de la Escosura, 2017).

This paper contributes to the development of the existing literature on the study of the historical relationship between height, biological well-being and life expectancy, providing new evidence on two aspects. First, it studies the relationship between height and life span over the very long-term. There is very little literature on this issue in the very long-term, for this reason, this paper try to shed light on the mechanisms underlying height's relationship to mortality and its possible change over time. Second, this study provides evidence regarding the influence of the environmental context and socioeconomic variables both on biological well-being and on the individual's life span. For this analysis, the study uses multivariate regressions in the long-term based on family variables (such as family size), individual socioeconomic variables (such as occupation) or health factors (such as dying during an epidemic period).

2. STUDY AREA

This study focuses on a rural area in Aragon, in north-east Spain (see Figure 1). The border of the area is 19 km away from the city of Zaragoza, the regional capital. The area of study comprises 14 villages: Alfamén, Aylés, Botorrita, Codos, Cosuenda, Jaulín, Longares, Mezalocha, Mozota, Muel, Torrecilla de Valmadrid, Tosos, Valmadrid and Villanueva de Huerva. It covers around 500 kms^2, with a population of around 8,000 inhabitants in 1860, 8,200 in 1900 and 10,700 in 1940 (for more details on a local level, see Table 1). These localities were selected because they form a homogeneous area, with an agriculture and population distribution typical of inland Spain, and because they have both parish and military data. The study area has been limited to 14 localities due to the availability of data and the costly and time-consuming methodology used.[2] The population mostly lived in nuclear households and worked in agriculture (mostly cereals and vineyards) and sheep grazing. Until the mid-twentieth century, 80% of the male working population was engaged in the agricultural sector where most of the population enjoyed living standards close to subsistence levels (Marco-Gracia, 2018b). All the

[2] We made an attempt to extend the study area with data from new localities nearby (in the province of Zaragoza). However, none of the localities fulfilled the double requirement of preserving individual military data from the nineteenth century and preserving the parish archives in the long term (many Aragonese parish archives were destroyed during the Spanish Civil War, including all the localities bordering the study area to the east).

agriculture in the area was in unirrigated areas except for the land near the river Huerva, where fruit and vegetables were cultivated.

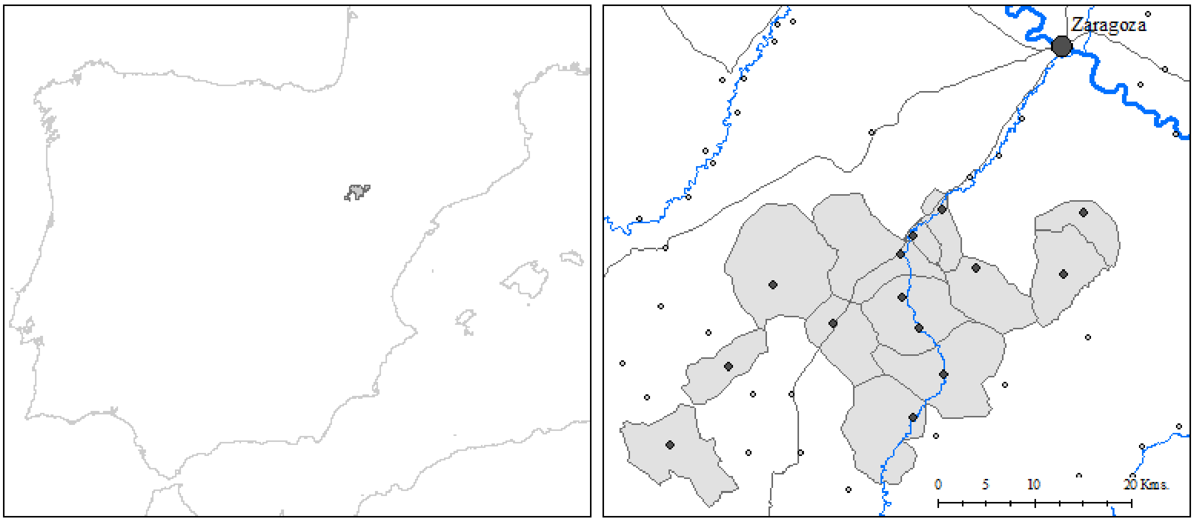
Table 1. Population of the villages in the sample 1860-1981

	Population			
	1860	1900	1940	1981
Alfamén	604	639	1,347	1,283
Aylés	45	26	47	0
Botorrita	294	350	557	382
Codos	1,232	1,195	938	355
Cosuenda	1,451	1,270	929	482
Jaulín	390	348	528	334
Longares	1,120	1,329	1,385	959
Mezalocha	544	482	660	357
Mozota	292	372	404	158
Muel	1,223	1,206	1,605	1,330
Torrecilla de Valmadrid	164	77	94	32
Tosos	682	865	801	297
Valmadrid	203	210	219	89
Villanueva de Huerva	690	970	1,158	771
TOTAL	7,926	8,196	10,672	5,632

Source: Spanish Statistical Institute (www.ine.es/intercensal/) and Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

This region underwent a process of economic modernisation from the second half of the nineteenth century, coinciding with the first wave of globalisation. The economic growth continued for most of the twentieth century despite economic and social shocks (Germán, 2012). This economic modernisation was particularly prominent in the regional capital, with the rural areas lagging behind (Germán, 2000). The Spanish Civil War constituted a strong negative shock to Aragon's economic modernisation, from which it did not recover until the 1960s (Germán, 2012). Most of the industries were located in the Ebro Valley, relatively close to the area of study, which may have favoured rural-urban migration (Silvestre, 2005).

Figure 1. Area of study: Middle Huerva (Aragón, Spain)



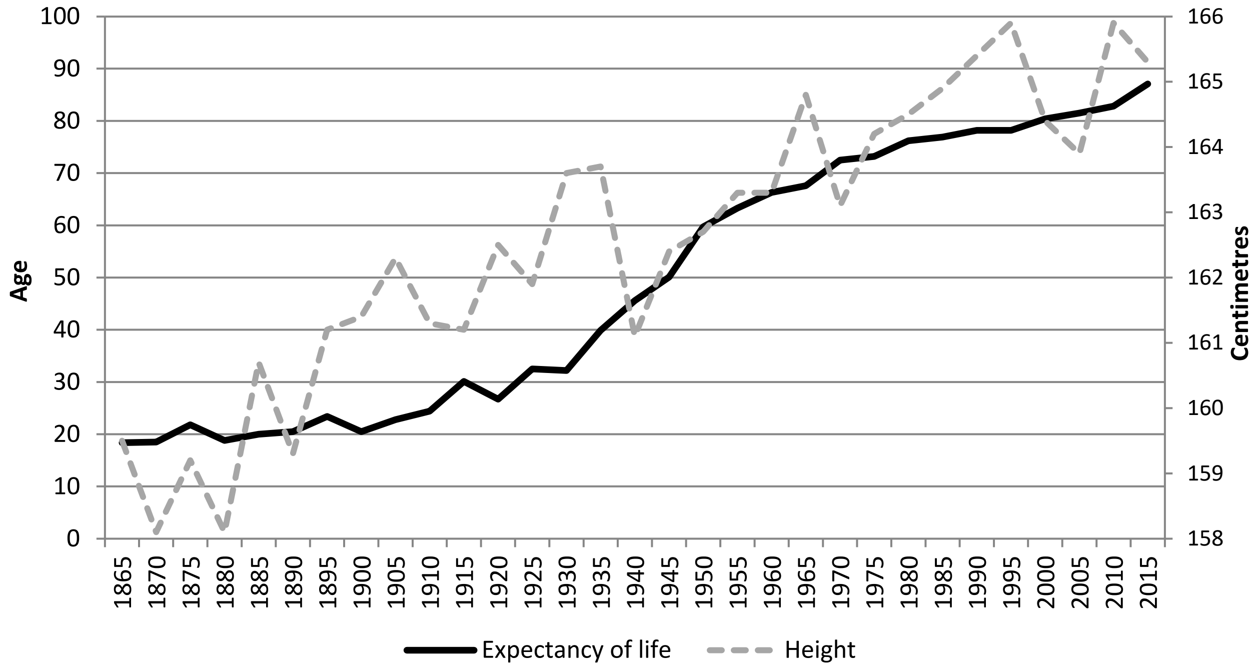
Source: Own elaboration.
Note: Dark dots indicate the villages studied (except Zaragoza, the provincial capital) and the corresponding shaded areas refer to their municipal boundaries.

The rural areas of the Ebro Valley specialised in agricultural products for the Spanish domestic market, such as cereals, sugar beet and sheep meat (Germán, 2012). However, in the last third of the nineteenth century, wine production grew considerably in order to supply the French market which was suffering from the consequences of the phylloxera plague that had struck the country. As a result, there was significant agricultural development in the valley areas, while the mountainous extremes to the north (Pyrenees) and south (Iberian System) experienced a severe crisis as a result of the recession in their traditional economy (Collantes and Pinilla, 2004).

At the demographic level, in our area of study, the average fertility rate was relatively stable at around 6-7 children for complete families until 1900 and declined thereafter following the fertility transition. Infant and child mortality rates were very high and only around half of the children survived to their fifth birthday. As was the case in the country as a whole, mortality rates began to decline in the last third of the nineteenth century due to the reduced incidence of epidemic crises and water- and food-borne infectious diseases in a process known as “epidemiological transition” (Marco-Gracia, 2017). Anthropometric evidence also indicates that biological well-being were low: the average male height was around 160 centimetres in the mid-nineteenth century, well below their European counterparts or their fellow Spaniards in other regions (Quintana-Domeque et al., 2012; Martínez-Carrión et al. 2016; Hatton and Bray, 2010).

During this long studied period in the article, Spain experienced a significant improvement in its living, health and nutritional conditions (Nicolau, 2005; Moreda et al., 2015). Figure 2 shows the consequences of these improvements on the evolution of height and life expectancy. We can see that the upward evolution of height and life expectancy in our study area is consistent with the Spanish and European evolution. Life expectancy was calculated by taking the entire population residing in the study area (not just conscripts). According to Figure 2, life expectancy has increased in the last 150 years from less than 20 years to more than 80 years. The evolution of stature was calculated for conscripts and plotted according to their five-year period of death (For a comparison of height by decade of birth see Figure A1 of the Appendix). The average height has also increased by almost 10 centimetres in the same period as a result of these improvements.

Figure 2. Life expectancy and heights (according to date of death) in the area of study, 1860-2019



Notes: In the figure we compare the evolution of the expectancy of life (taking into account the whole population of the study area, including all children, men and women who died) and the average height of the conscript plotted on the quinquennium of death.
To see the comparison of average height according to municipality and decade of birth (period in which data are available in municipal archives) see Figure A3 of Appendix.
Source: Parish registers of death and conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain). For more information of these archives see Table 2.

3. DATA & METHODS

3.1 Data

We have analysed three types of data: 1. height data from military conscription; 2. individual demographic data from parish registers (up to 1950), surveys (from 1950) and in recent years mortality data from sources linked to cemeteries (mainly date of death and age at death); 3. Socio-economic data on occupation and literacy from censuses, population lists and parish registers.

We have used the height data for military conscription referring to those enlisted between 1855 and 1939 in the fourteen afore-mentioned villages (Table 2). 94.1% of the data were obtained from the records kept in the municipal archives of each village. To complete the sample, we requested a copy of the available conscriptions in the Historical Military Archive of Guadalajara. From this archive, we were able to identify 88 new individuals. The total sample included 1,488 complete life courses. In Table 2 we can see the start-year and end-year of the available data for the conscriptions. Unlike the selection biases found in other countries, Spanish military recruitment sources include all individuals of that generation. The existence of a universal recruitment system since the 1830s ensured that most recruits were measured, except for fugitives, migrants and those who had died. Although several legal mechanisms existed between 1837 and 1936 to avoid compulsory military service (cash redemption, replacement and soldier quota), it is important to note that all of them were implemented after measurement (Puell de la Villa 1996; Verdejo Lucas, 2004). Individuals rejected for military service because of their short height or health problems were registered with the rest of the conscripts.

During the period analysed, the age of conscription varied over time.[3] Thus, we have standardised the average height to the age of 21 years. To do this, we have used the same strategy followed by Ayuda and Puche-Gil (2014) based on calculating the 50th percentile of the three age groups (19, 20 and 21 years), adding 1.2 cm to the height of the 19 year-olds and 0.4 cm to that of the 20 year-olds. As expected, height growth was higher in the

[3] During the period 1856-1885 the age of military conscription was 20 years old; during the period 1885 (second call-up)-1899 it was 19 years old; between 1901 and 1905 it was 20 years old and between 1907-1939 it was 21 years old.

19 year old age group, as they had a greater chance of growing taller at the onset of the adolescent growth spurt. Our results are similar to those obtained in other Spanish regions (Martínez-Carrión and Moreno-Lázaro, 2007; Ramón Muñoz, 2011; Ayuda and Puche-Gil, 2014). In general, the distribution of the height data is close to normal for the whole period (Appendix, Fig. A2), although we can observe some imperfections due to the low sample size, and the height-heaping tendency exercised by rural doctors. We have tested the null hypothesis of normality of average height and we cannot reject the null hypothesis for a significant level of 5%.

Table 2. Year of first observation and last observation in demographic data (parish archives, death data and surveys) and conscription (at 21 years) by village

	Conscriptions (year of recruitment)		Family reconstitution	
	First obs.	Last Obs.	First obs.	Last Obs.
Alfamén	1929	1985	1716	2019
Botorrita	1928	1977	1642	2019
Codos	1921	1982	1859	2016
Cosuenda	1918	1983	1551	2016
Jaulín	1940	1986	1560	2019
Longares	1849	1985	1473	2019
Mezalocha and Aylés	1919	1975	1557	2019
Mozota	1856	1965	1608	2019
Muel	1940	1972	1610	2019
Torrecilla de Valmadrid	1921	1942	1586	2017
Tosos	1935	1984	1547	2019
Valmadrid	1938	1948	1852	2017
Villanueva de Huerva	1930	1999	1573	2019
Historical Military Archive of Guadalajara (all villages)	1880	1940	-	-

Source: Parish archives of Alfamén, Botorrita, Codos, Cosuenda, Jaulín, Longares, Mezalocha, Mozota, Muel, Torrecilla de Valmadrid, Tosos, Valmadrid and Villanueva de Huerva. To access the data it is necessary to contact the priest of that Church through the archdiocese of Zaragoza (www.archizaragoza.org). For conscription and call-up records (prior appointment is needed): Municipal archive of Alfamén, Botorrita, Codos, Cosuenda, Jaulín, Longares, Mezalocha, Mozota, Muel, Tosos, Villanueva de Huerva, Historical archive of Zaragoza -for the data of Torrecilla de Valmadrid- and Historical Military Archive of Guadalajara.

The family and demographic event analysis is based on the complete Church registers of these 14 villages, which provide high-quality information on all the baptisms, marriages and deaths that occurred between the sixteenth century and 1950.[4] In Table 2 we can observe the start-year and end-year of the available data for the parish. To obtain similar data for the period after 1950, 1,074 interviews were conducted among relatives of the individuals analysed.[5] The mortality data were completed with information obtained from public sources linked to the cemeteries of each village, including information on the identity of the deceased, the date of death, their age and, exceptionally, the cause of death. The database was constructed following the family reconstitution method devised by Fleury and Henry (1956). It includes all individuals who were born and baptised in the reference parishes or who migrated to them and were registered. The dataset contains information about approximately 125,000 individuals, enabling us to reconstitute the life history of these individuals and their families.

The occupation and literacy data of the conscripts analysed and their fathers were extracted from population lists (1857 and 1860), electoral censuses (1890, 1894, 1900, 1910, 1920, 1930, 1934, 1945, 1951, and 1955), and the parish registers[6], linking them to population records for each individual.

The sample has several limitations. Firstly, the small sample size does not allow us to delve into smaller sub-periods or to carry out more in-depth analyses. Secondly, the study only focuses on the male population. This could be limiting the extrapolation of our results because the relationships between stature, mortality and life expectancy are not well understood and may not be the same for men and women. Last but not least, the sample is composed of individuals who survived until age 21. This may have certain risks,

[4] For more details about the 'Alfamén and Middle Huerva Database' see Marco-Gracia (2017, 2019).
[5] We enquired about information regarding dates of demographic events, occupation, and education.
[6] The data appear randomly depending on the parish priest.

as recent literature has warned that sample selection bias and other forms of bias, such as collider bias, could distort causal results (for an overview of this issue: Schneider, 2020).

During the twentieth century the Spanish population experienced a progressive migration from rural to urban areas (Silvestre, 2005). In the 1960s, for example, 5.7 million people (17.7% of total population) changed their residence (Nicolau, 2005; Collantes and Pinilla, 2011). In the case of Aragon, between 1951 and 1970 the region lost 102,000 inhabitants (Nicolau, 2005: 153). These migrations condition also the size of the sample since they reduce the number of cases that can be followed until death. In this sense, highly educated individuals had more incentives to migrate given the few job opportunities for them in rural areas, and landowners had incentives to remain in their localities of origin (Marco-Gracia, 2018c).

3.2 Variables

In Table 3 we can observe the distribution of our sample for several variables, including the average height and average life span. The place of residence (for 89.2% of the conscripts in the dataset the same as at birth) is an interesting control variable to determine whether there are significant differences between villages depending on the environmental and socioeconomic conditions. Birth decade is also a good indicator both of the process of demographic modernisation and of the effects of the social, economic and political context on the process of improving living conditions. Literacy allows us to gain a greater insight into the effect that accessing education had on biological well-being. The literacy rate increased in Spain from 27 percent in 1860 to 73 percent in 1930 (Núñez, 2005). In our study area, men and women born in the 1930s were the first generation to achieve full literacy (Marco-Gracia, 2018b). Likewise, the level of education can serve as a proxy for the economic and time investments made by parents.

Table 3. Characteristics of the sample in relation to the average height and life span, birth cohorts 1835-1939, 1,488 observations

	Variables	Cases	%	Average height	Standard deviation	Average life span	Standard deviation
Locality of residence	Alfamén	211	14.18	165.0	4.2	70.7	1.1
	Aylés	54	3.63	164.5	10.4	74.5	2.2
	Botorrita	60	4.03	167.1	11.1	69.6	2.3
	Codos	116	7.80	160.0	5.7	71.5	1.6
	Cosuenda	151	10.15	165.1	4.7	67.7	1.5
	Jaulín	39	2.62	165.5	9.8	73.4	2.8
	Longares	472	31.72	163.0	2.8	63.9	0.8
	Mezalocha	51	3.43	165.2	7.5	70.9	2.2
	Mozota	88	5.91	164.3	6.5	63.1	2.1
	Muel	87	5.85	164.4	6.4	68.9	1.7
	Torrecilla de Valmadrid	4	0.27	163.0	12.7	75.2	4.7
	Tosos	35	2.35	165.7	9.9	74.4	2.3
	Valmadrid	6	0.40	166.4	15.6	80.9	3.3
	Villanueva de Huerva	114	7.66	164.2	6.1	73.5	1.6
Birth decade	1830 (1836-1839)	23	1.55	156.9	12.2	62.1	3.8
	1840	82	5.51	162.1	7.0	56.5	1.8
	1850	25	1.68	160.5	12.9	55.6	3.7
	1860	55	3.70	161.1	8.03	59.8	2.5
	1870	62	4.17	161.9	7.9	62.4	2.0
	1880	65	4.37	162.8	6.3	64.0	1.9
	1890	97	6.52	163.9	5.3	64.2	2.0
	1900	258	17.34	163.5	3.7	69.1	1.1
	1910	233	15.66	164.6	4.5	69.8	1.2
	1920	393	26.41	164.8	3.3	73.3	0.8
	1930	195	13.10	166.0	4.2	70.0	1.0
Literacy	Illiterate	131	8.80	162.8	6.2	68.0	1.5
	Literate	1,110	74.60	164.6	1.8	70.1	0.5
	Unknown	247	16.60	161.4	4.0	59.9	1.1
Occupation	Low skilled worker	705	47.38	163.4	2.4	66.8	0.7
	Farmer	590	39.65	164.4	2.8	69.0	0.7
	Artisan	67	4.50	165.0	7.6	63.4	2.4
	Upper class	15	1.01	167.0	16.9	70.3	6.2
	Other	111	7.46	164.1	4.9	76.5	1.1
Father's occupation	Low skills employee	726	48.79	163.7	2.4	67.5	0.7
	Farmer	497	33.40	164.6	3.0	69.8	0.8
	Artisan	78	5.24	163.8	7.7	67.0	2.0
	Upper class	15	1.01	165.5	10.9	65.8	4.4
	Other or unknown	172	11.56	163.2	4.8	68.1	1.4
Motherless	No	1,388	93.28	164.0	1.7	68.4	0.5
	Yes	100	6.72	163.4	5.9	66.1	1.8
Fatherless	No	1,389	93.35	163.9	1.7	68.3	0.5
	Yes	99	6.65	164.6	6.5	67.6	1.8

Number of living siblings	0 siblings	99	6.65	164.3	6.6	71.9	1.5
	1-2 siblings	410	27.55	164.9	3.0	74.3	0.7
	3-4 siblings	960	64.52	163.6	2.1	65.3	0.6
	5 or more siblings	19	1.28	162.2	11.6	69.8	2.1
Family support at death	0-2 people	817	54.91	163.7	2.2	65.7	1.0
	3-5 people	442	29.70	164.1	3.2	68.4	0.6
	6 or more people	229	15.39	164.6	4.2	72.6	0.9
Physical Appeals	No	1,176	79.03	164.2	1.7	68.7	0.5
	Yes	112	7.53	161.0	8.1	63.5	2.0
Number of economic crises	0 crises	261	17.54	164.0	4.1	68.1	1.2
	1 crisis	496	33.33	163.0	2.8	65.1	0.8
	2 crises	180	12.10	163.6	4.9	64.3	1.5
	3 crises	551	37.03	164.9	2.8	72.4	0.6
Dying in an epidemic year	Yes	18	1.21	162.7	11.7	54.8	4.6
	No	1,470	98.79	164.0	1.7	68.4	0.5
Dying during the war and post-war	War (1936-1939)	19	1.28	166.0	12.3	42.5	5.0
	1st post-war (1940s)	82	5.51	161.8	6.6	54.6	2.0
	2nd p-w (1950-1958)	84	5.65	163.0	7.0	55.4	1.9
	No war or post-war	1,303	87.57	164.1	1.8	70.3	0.5

Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

Occupation is a useful proxy to know the income level and living standards of individuals. Blum (2013b) points out that there is a clear relationship between the occupational category of the father and that of the son. In our study, we have used parental occupation as an indicator of living standards and the socioeconomic status of the conscript's family. Due to the particular occupational distribution of this area[7], we have divided the conscripts into five occupational categories: a) the first group consists of agricultural day-labourers and unskilled employed people; b) the second group is composed of farmers; c) the third group consists of artisans (potters, bakers, blacksmiths, tailors, glassmakers, etc); d) The fourth category includes conscripts with non-manual skilled occupations that

[7] We have not used international classifications (such as HISCLASS or SOCPO) because of the high concentration of individuals in two categories (farmers and low skilled workers), and the low occupational variability. We believe that our classification is clear and efficient for the data available in the study area.

required a medium or higher level of education, such as doctors, teachers, veterinarians, notaries, bankers, nurses or station masters; and e) 'Others', includes the rest of the professionals that we cannot identify their skill level, covering a range of occupations, such as military personnel, drivers of diverse vehicles, etc. In our case, only 39.7 percent of the children shared the same socioeconomic group as their parents, even though we have grouped the occupations into just five groups. This is because the second half of the nineteenth century and the twentieth century constituted a period of economic and social transformation in rural Spain.

For the first analysis (determinants of height) we have included some variables related with the family of origin. On the one hand, we have identified children who lost their mother (motherless) or father (fatherless) before the age of 15. None of them lost both parents before the age of 15. The loss of a parent during childhood and youth has been shown to be linked to low biological well-being in Spain (Reher and González-Quiñones, 2003; Marco-Gracia, 2021). On the other hand, we identified the number of siblings who lived with the conscripts (and competed for family resources with them) for at least five years. This variable can be of interest given that a large family size could be linked to greater limitations for family resources, affecting the biological well-being of conscripts (for a summary, see Öberg, 2017). For the second statistical analysis (determinants of life span), we have taken into account the number of direct living relatives (siblings, spouse and children) and residents in the same locality at the time of the individual's death. The aim of this variable is to analyse whether the presence of relatives who can help with care at old age had a positive effect on the life span.

Likewise, we have also introduced into our analysis of the determinants of biological well-being the number of economic crises experienced by the conscripts during their childhood and adolescence up to the age of 15. These crises could have had effects on food consumption, affecting to its growth process and reducing the height achieved. So, for the nineteenth century we have taken the series of wheat prices of the city of Zaragoza (Peiró, 1987) and identified the years in which the price rose at least 10% above the average after removing the trend (Hodrick and Prescott, 1997). These years were 1836, 1837, 1841, 1846, 1855, 1856, 1867, 1881, 1891, 1896 and 1897. For the twentieth century, we have information on the evolution of the GDP per capita in the province of Zaragoza[8]. We have considered as years of economic crisis those when the GDP per capita fell below the levels of the previous year. These years were: 1910, 1926, 1928, 1931, 1933, 1936, 1937, 1938, 1945, 1949 and 1953.[9]

Spanish military conscripts provide other data of interest. Particularly noteworthy are the data on the state of health at the time of measurement. Thus, we have included in our analysis the information of appeals for exemption on physical grounds submitted by the conscripts themselves with the intention of legally avoiding military service. We have only taken into account those appeals that were accepted by the authorities. Another variable analysed is whether the year of the individual's death was a pandemic year. There were two important pandemics in our study period: 1. the cholera outbreak of 1885, which caused the death of more than 10% of the population in some villages; and 2. the 1918-1920 Spanish flu pandemic, which in Spain caused around 260,000 deaths (Echeverri, 1993).

We have also paid special attention to the greatest social and economic shock of the twentieth century in the study area, the Spanish Civil War of 1936-1939 and the long post-war period. Although none of the individuals analysed were killed in action, during the war and post-war years, socioeconomic and biological inequalities tended to increase

[8] Personal communication of Prof. Vicente Pinilla (Universidad de Zaragoza).
[9] For more information on this issue, see Marco-Gracia (2017).

(Martínez-Carrión and Puche, 2009; Ayuda and Puche-Gil, 2014; Gonzalez-Madrid and Ortíz-Heras, 2017; Cañabate and Martínez-Carrión, 2018; Cámara et al., 2019). In this sense, we have introduced a variable into our analysis that differentiates between the years of the war conflict (1936-1939) and the first two decades of the post-war period (1940s-1950s). The area of study corresponds to the area occupied by the rebel side (Francoist) during the whole of the war, very close to the war front. The inhabitants of these localities were only able to cultivate part of their properties and had to bear the high economic burden of supporting the nearby troops and the surrounding infrastructure (such as airfields or anti-aircraft batteries).

Finally, we have also included in the analysis as a control variable the causes of death because it could be correlated with age at death. We have identified causes of death for 879 individuals distributed throughout the study period. They have been classified using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10). In Table A4 of the appendix we can observe the distribution of the causes of death by height group. The results show an almost homogeneous distribution, without significant differences between groups. The distribution of adult mortality by cause of death changed slightly over time, with mortality from infectious diseases decreasing and mortality from degenerative diseases and cancer increasing. However, these variations were homogeneous for all height groups. We include cause of death in the analysis because differences in age at death could be related with the cause of death of the individual (The Emerging Risk Factors Collaboration, 2012). For example, people who died from external injuries (especially road traffic accidents or violence) would be more likely to have died at a younger age.

Within the analysis for the complete period (birth cohorts 1835-1939), we have controlled for the existence of a relationship between height and age at death in three subperiods: 1.

Birth cohorts of 1835-1869: this period was prior to the demographic transition and was characterised by high mortality and high fertility rates, 2. Birth cohorts of 1870-1899: the period in which the demographic transition began with an initial reduction in childhood and adult mortality, high marital fertility and an increase in the average family size; 3. Birth cohorts of 1900-1939: a period of demographic modernisation with a significant reduction in infectious diseases, infant mortality and marital fertility, which resulted in a progressive increase in life expectancy (Nicolau, 2005).[10]

3.3 Statistical analyses

The article is based on a combination of descriptive and regression analyses. The descriptive analysis, such as the one that appears in the following subsection and at the end of the results section, focuses on the study of the temporal evolution of the height-age at death relationship. In these descriptive analyses we try to introduce the perspective of temporal evolution, given that the small sample size does not allow us to do so through our regressions without conditioning the robustness of the analysis. Thus, in the following subsection, we have analysed the evolution of the mean age at death as a function of the year of death and the age-group. The aim of this analysis was to find out the effect of the main shocks (and especially of the Spanish Civil War) on this relationship. In this way, we can be aware of how the specific context of Spain (not shared by other countries) influences the results before performing regression analyses. We have also used descriptive analysis elsewhere in the article and the appendix, and especially at the end of the results section to highlight the convergent trend between height and age-at-death.

[10] The characteristics of the sample (in a similar way of table 3) for the three subperiods are presented in the Appendix in Tables A1, A2, A3.

We have also conducted regression analyses to investigate the relationship between height and age at death of conscripts controlling for several significant factors such as socioeconomic status or family size. For the statistical analysis of our data we have used ordinary least squares (OLS) linear regressions with heteroskedasticity-robust estimation. In this case we have conducted three sets of analyses with different dependent variables. In the first group (Table 4), we have used height as the dependent variable to approximate its determinants. In the second group (Table 5), we have taken as a dependent variable the age at death of the conscripts, trying to analyse whether there was a relationship between this age at death and height, as a variable on which collapsed the early life conditions and other factors. Finally, in the third group of variables (Table 6), we have also used age at death as the dependent variable, but we have made three first models with individuals who died before the age of 65 and three last models with individuals who died at the age of 65 or older. The models can be denoted as follows:

$$y_i = \beta_1 * X_{1i} + \beta_2 * X_{2i} + \beta_3 * X_{3i} + ... + \varepsilon$$

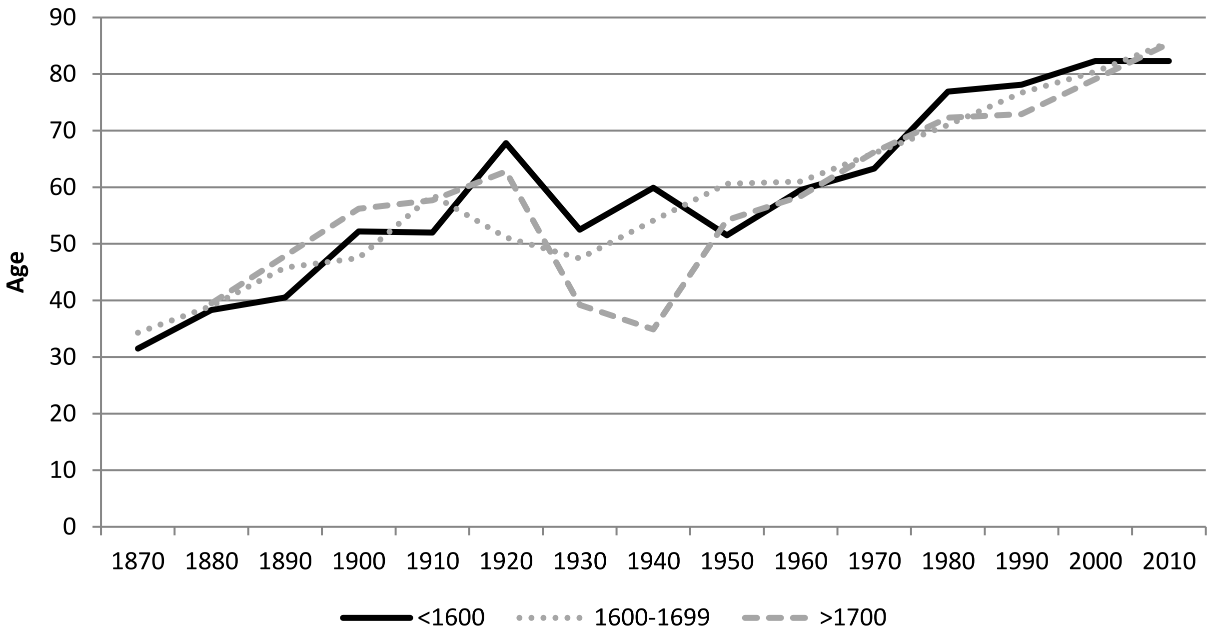
where y is the dependent variable described in the previous paragraph, for an individual i, β_n, is the parameter, X_n denotes the variables described in the previous section used in each model and ε is the error term.

3.4 Descriptive analysis: temporal evolution of age at death according to death

In Figure 3, we have calculated the average age at death of the conscripts according to height group and decade of death for the period 1890-2019. Therefore, we have only taken into account men over 21 years of age and calculated average age at death for each height group every 10 years. The objective is to observe the evolution over time and the effect of the main economic and social shocks, paying special attention to the case of the Spanish Civil War (1936-1939). We found three differentiated stages. In the first stage

(1870s-1920s), we can observe an important increase in life span, with the individuals analysed showing a positive relationship between life span and height. The improvement in biological living standards at this stage can be partly associated with the advance of the demographic and epidemiological transition processes, as well as with relative improvements in nutritional conditions (Nicolau, 2005; Pérez Moreda et al., 2015; Martínez Carrión et al., 2016). In the second stage (1930s-1950s), we can observe that there was a significant reduction in the life span due to the negative impact of the economic crises of the 1930s, the Spanish Civil War and the harsh post-war period. It is particularly interesting that these shocks did not affect all the height groups equally. In relative terms, short conscripts were less affected, although the deterioration of their life expectancy lasted until the 1950s. The data suggest that the shock of the civil war was more pronounced for families with better living standards. The richest individuals bore most of the economic burdens related to the proximity of the war front, including the demands for money to build new war infrastructure in nearby locations. Being mostly landowners, they were also strongly affected by land expropriations and limitations for cultivating. The results in Figure 3 contrast with those obtained in Figure 2 for life expectancy for society as a whole. While life expectancy increased throughout the period (largely boosted by falling infant mortality), the age at death of adult men suffered for decades from the consequences of the negative shocks of 1930s.The third stage (1960s-present day) is a long period with significant improvements in nutrition and health (Cussó, 2005; Nicolau, 2005; Spijker et al., 2012; Pérez Moreda et al., 2015). In this stage growth was similar in the three height groups but slightly more favourable for short men. In the 2000s, average age at death exceeded 80 years for all groups.

Figure 3. Evolution of age at death plotted according to height group and decade of death, 1890-2019.



Source: Parish registers, conscription and call-up records; historical municipal and parish archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara.

4. RESULTS

First, we have analysed some of the determinants of biological well-being in our study area, using as a dependent variable the height of men at 21 years. In this way, we seek to determine which factors are behind the relationship between height and life span. Table 4 presents the six regressions carried out. In general, the results obtained reveal that biological well-being at the age of 21 was conditioned by socio-economic, educational, health and family conditions. Conscripts from the poorest parental socio-economic group (low skilled workers) had a shorter height, almost 1 cm less on average than the children of farmers. The literacy of the conscripts also proves to be strongly related to their biological well-being, coinciding with previous anthropometric research (Quiroga, 2003; Martínez-Carrión and Puche, 2009; Cámara et al., 2019). Table 4 also reflects that individuals who claimed to suffer from physical problems in order to evade military service were substantially shorter (on average 3.2 cm) than those who made no such claim. In fact, this is the factor with the most influence on biological well-being according to our results, thus confirming the importance of health status on physical growth. Finally, in relation to family of origin, the results confirm that being motherless reduced biological well-being in the study area. While being fatherless does not seem to have had a significant effect on height. Similarly, a high number of siblings seem to have had a negative effect on height, so the resource dilution hypothesis could be explaining what have occurred among the offspring of the family (this possibility has been discussed in the next section of the paper).

Table 4. Regression results. Determinants of height in the Aragonese area of study, birth cohorts 1835-1939

Dependent variable: Height at 21 years (min. 130 cm – max. 195 cm)							
Variable	**Categories**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Father's occupation	Farmer	(ref.)					
	Low skilled worker	-7.84**	-10.61***	-7.55**	-10.52***	-7.88**	-10.73***
		(3.73)	(3.77)	(3.70)	(3.74)	(3.70)	(3.75)
	Artisan	-4.46	1.72	-4.04	1.90	-3.46	2.42
		(7.77)	(7.61)	(7.70)	(7.55)	(7.70)	(7.55)
	Upper class	8.14	1.27	9.01	2.77	10.52	4.69
		(16.67)	(16.27)	(16.55)	(16.16)	(16.53)	(16.16)
	Other or unknown	-10.45*	-14.61**	-8.52	-13.76**	-9.94*	-15.03**
		(5.65)	(5.83)	(5.62)	(5.80)	(5.65)	(5.83)
Literacy	Illiterate	(ref.)					
	Literate	16.36***	10.56*	11.75*	7.10	11.64*	7.39
		(5.92)	(5.91)	(5.99)	(5.94)	(5.98)	(5.94)
	Unknown	-15.43**	1.30	-16.59**	0.42	-16.22**	-0.30
		(6.93)	(8.08)	(6.98)	(8.04)	(6.97)	(8.05)
Physical appeals	No	(ref.)					
	Yes			-29.80***	-28.87***	-28.76***	-28.00***
				(6.23)	(6.14)	(6.24)	(6.15)
Number of economic crises	0 crises	(ref.)					
	1 crisis			-3.69	-2.02	-3.67	-2.20
				(4.94)	(4.92)	(4.93)	(4.91)
	2 crises			3.77	9.04	3.80	8.69
				(6.28)	(6.31)	(6.27)	(6.31)

	3 crises			6.09	3.66	5.36	3.09
				(4.76)	(4.78)	(4.78)	(4.80)
Motherless	No	(ref.)					
	Yes					-4.91*	-3.21**
						(6.57)	(6.42)
Fatherless	No	(ref.)					
	Yes					11.48	12.86
						(6.62)	(6.45)
Number of living siblings	0 siblings					0.17	-1.61
	1-2 siblings	(ref.)					
	3-4 siblings					-9.78***	-8.12**
	5 or more siblings					-19.12	-10.50
	Intercept	1635.5***	1609.9***	1639.5***	1610.6***	1646.1***	1616.8***
Control Village		NO	YES	NO	YES	NO	YES
Control Birth decade		NO	YES	NO	YES	NO	YES
	Sample size	1,488	1,488	1,488	1,488	1,488	1,488
	Adjusted R^2	0.04	0.11	0.06	0.12	0.07	0.13

Notes: OLS estimates; *se* denotes robust standard error.
Source: Parish registers, censuses and conscription and call-up records; historical municipal and parish archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).
* Statistical significance at 10% level.
** Statistical significance at 5% level.
*** Statistical significance at 1% level.

In Table 4 we have shown that height is strongly correlated with several socio-economic and environmental variables of individuals' childhood. From this point on, we will use height as a proxy on which the variables on early life conditions have collapsed. The relationship between height and life span would therefore be the consequence of early life conditions on life span.

Next, we analysed the determinants of life span knowing that this is composed of both genetic factors and living conditions. Therefore, all the variables used (except height) were obtained from observations after the age of 21 years. In Table 5 we can observe the results of six regressions carried out to estimate these determinants. In model 1, we introduced the variable of height as a continuous variable, analysing exclusively this variable to establish a first correlation between the two main variables of the study. However, the results of this first model may have been biased by the increasing trend of mean height and age at death over time. In models 2 to 6, we introduced height categorised by quintiles for the whole period (for more information on distribution, see the note accompanying Table 5), and weighed by subperiod (birth cohorts 1835-1869, 1870-1899, and 1900-1939). In models 3 to 6 the height has been combined with other socioeconomic, family and control variables. In all of them we found that the relationship between height and life span is significant and positive among men born between 1835 and 1939. The results have a high level of significance and show that short conscripts had shorter life spans, almost four year on average of difference between shorts and conscripts in the intermediate group. Meanwhile, tall had longer life spans than the intermediate group, almost one year difference on average.

Table 5. Regression results. Determinants of life span in the Aragonese area of study, birth cohorts 1835-1939

Dependent variable: Exact age at death (min. 22.0 – max. 101.2)							
Variable	**Categories**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Height	Continuous variable	0.02***					
Height categorised by quintiles weighted by period (++)	Q1 Short		-3.60**	-3.40**	-3.07**	-2.71**	-2.82**
			(1.45)	(1.41)	(1.33)	(1.32)	(1.32)
	Q2 Medium-short		-3.32**	-3.38**	-2.66*	-2.63**	-2.68**
			(1.42)	(1.44)	(1.36)	(1.29)	(1.29)
	Q3 Average	(ref.)					
	Q4 Medium-tall		0.58	0.54	0.41	0.06	0.02
			(1.46)	(1.45)	(1.41)	(1.35)	(1.35)
	Q5 Tall		0.74*	0.75*	0.74*	0.48	0.46
			(1.50)	(1.48)	(1.37)	(1.32)	(1.32)
Occupation	Farmer	(ref.)					
	Low skilled worker			-5.92**	-5.91***	-4.87**	-5.15**
				(2.29)	(2.17)	(2.09)	(2.09)
	Artisan			-2.07**	-1.69*	-1.82*	-2.00**
				(0.99)	(0.94)	(0.94)	(0.94)
	Upper class			0.46	2.58	4.62	4.47
				(4.64)	(4.40)	(4.24)	(4.23)
	Other			7.45***	6.79***	6.49***	6.33***
				(1.84)	(1.74)	(1.78)	(1.78)

Dying in war or post-war years	No	(ref.)					
	Spanish Civil War (1936-1939)				-27.17***	-21.59***	-21.52***
					(3.89)	(3.80)	(3.80)
	1st decade of post-war (1940-1949)				-15.36***	-11.85***	-11.59***
					(1.92)	(1.90)	(1.89)
	2nd decade of post-war (1950-1958)				-14.74***	-11.72***	-11.74***
					(1.90)	(1.84)	(1.83)
Dying in an epidemic year	No	(ref.)					
	Yes				-16.31***	-13.47***	-13.58***
					(4.00)	(3.86)	(3.85)
Relatives alive at death in the same locality	0 to 2 people						2.43*
							(1.45)
	3 to 5 people	(ref.)					
	6 or more people						-1.23
							(1.85)
	Intercept	28.77***	66.09***	66.97***	69.64***	65.81***	64.44***
Control Cause of death		NO	NO	NO	NO	YES	YES
Control village		NO	NO	NO	NO	YES	YES
Control birth decade		NO	NO	NO	NO	YES	YES
	N	1,488	1,488	1,488	1,488	1,488	1,488
	R-sq	0.01	0.01	0.03	0.13	0.22	0.23

Notes: OLS estimates; *se* denotes robust standard error. (++) For the subperiod 1835-1869 the quintiles remain: Q1. <=1560; Q2. >1560 & <=1600; Q3. >1600 & <=1625; Q4. >1625 & <=1665; Q5. >1665. For the subperiod 1870-1899 the quintiles remain: Q1. <=1585; Q2. >1585 & <=1616; Q3. >1616 & <=1649; Q4. >1649 & <=1684; Q5. >1684. For the subperiod 1900-1939 the quintiles remain: Q1. <=1595; Q2. >1595 & <=1633; Q3. >1633 & <=1665; Q4. >1665 & <=1700; Q5. >1700.
Source: Parish registers, censuses and conscription and call-up records; historical municipal and parish archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).
* Statistical significance at 10% level.
** Statistical significance at 5% level.
*** Statistical significance at 1% level.

Table 5 highlights the importance of socio-economic variables in life span. Models 3 to 6 find a relationship between occupation and life span, also found in southern Spain in a similar period (Luque, 2020). Likewise, our results reveal that epidemics, war conflicts and institutional changes also influence the age at death. In Spain, the Civil War of 1936-1939 negatively affected the living and health conditions and the longevity of the population (Nicolau, 2005; Ortega and Silvestre, 2006; Pérez Moreda et al., 2015). Individuals who died during the war years had a 27.8 per cent shorter life span. Similarly, the post-war period had negative effects. The conscripts who died in the 1940s had a life span that was 15.7 years shorter and those who died in the 1950s lived 14.9 years less than the rest of the men in the sample. The variable 'dying in a pandemic year' is also significant. Those who died in a pandemic year had a shorter life span (almost eight years of difference).

Finally, in model 6 we included a variable with the number of living relatives residing in the same village at the time of the conscript's death. This variable is useful for learning about the effect of the care provided by relatives on life span. The results show (at 90% of significant) that the individuals with few relatives in the same locality were those with the largest life span (we have discussed this results in the next section).

In Table 6 we have replicated models 2 and 6 of Table 5 (in the case of model 6, without controls and with controls) for two subsamples according to age at death. We have divided the sample between those who died before the age of 65 and those who died later. The aim of this analysis is to find out whether the relationship between height and age at death is concentrated in certain age groups. The results should be taken with caution due to the low number of cases, especially for those under 65 years of age (518 conscripts). However, the results are illustrative. The positive relationship between height and life span holds for those under 65 years of age. The shortest were most likely to die young. These results are consistent with the literature on early life conditions in the long term (Smith et al., 2009; Bengtsson and Mineau, 2009; Marco-Gracia, 2021). Individuals with poor conditions during their childhood (approached through the proxy of height), were more likely to develop health problems that manifested themselves throughout adulthood, sometimes with mortal consequences. In the case of individuals aged 65 and over, most individuals have health problems, so the relationship between height and life span fades. Even so, in models 4 and 5 of Table 6, the existence of a 'shortness penalty' is maintained, with shorter individuals continuing to be more likely to die at an earlier age.

In the rest of the results obtained, for those under 65 years of age, the effects of the Spanish Civil War and pandemics stand out, reducing the life span. Meanwhile, among old individuals having carried out hard work (such as that performed by day-labourers and people with low skills) reduced their age at death. It is also among individuals aged 65 and over that the positive effects of having few relatives alive are concentrated.

Table 6. Regression results. Determinants of life span in the Aragonese area of study according to age at death (under 65 vs. 65 and over), birth cohorts 1835-1939

Dependent variable: Exact age at death (min. 22.0 – max. 101.2)							
			Under 65 years			65 years and over	
Variable	**Categories**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Height categorised by quintiles weighted by period (++)	Q1 Short	-3.15*	-3.17*	-2.91*	-0.34*	-0.65*	-0.21
		(1.81)	(1.77)	(1.70)	(0.80)	(0.78)	(0.76)
	Q2 Medium-short	-0.98	-0.82	-1.32	-0.78	-0.51	-0.20
		(2.00)	(1.73)	(1.86)	(0.79)	(0.77)	(0.74)
	Q3 Average	(ref.)					
	Q4 Medium-tall	0.05	0.12	0.62	0.55	0.48	0.43
		(1.89)	(1.83)	(1.76)	(0.79)	(0.77)	(0.74)
	Q5 Tall	0.24*	0.78*	0.85	1.04	0.91	0.73
		(1.77)	(1.94)	(1.67)	(0.80)	(0.78)	(0.74)
Occupation	Farmer	(ref.)					
	Low skilled worker		-1.30	-1.15		-1.18**	-1.14**
			(1.19)	(1.20)		(0.54)	(0.54)
	Artisan		-2.91	-2.03		-1.51	-1.35
			(2.47)	(2.36)		(1.35)	(1.30)
	Upper class		-6.24	-7.62		4.84*	6.10**
			(5.80)	(5.55)		(2.49)	(2.41)
	Other		6.33*	6.70**		0.62	1.12
			(3.22)	(3.19)		(0.90)	(0.93)
Dying in war or post-war years	No	(ref.)					
	Spanish Civil War (1936-1939)		-18.97***	-16.01***		-4.05	-3.28
			(3.46)	(3.42)		(3.49)	(3.35)
	1st decade of post-war (1940-1949)		-5.19***	-4.92***		-5.58***	-3.66**
			(1.87)	(1.83)		(1.48)	(1.47)
	2nd decade of post-war (1950-1958)		-4.22**	-4.32**		-5.08***	-3.91***
			(1.87)	(1.79)		(1.44)	(1.41)
Dying in an epidemic year	No	(ref.)					
	Yes		-7.55*	-6.51*		-5.41*	-2.68
			(3.90)	(3.72)		(2.96)	(2.89)
Relatives alive at death in the same locality	0 to 2 people		0.76	0.71		3.05***	2.83***
			(2.01)	(1.91)		(0.85)	(0.82)
	3 to 5 people	(ref.)					
	6 or more people		1.35	0.54		-0.36	-0.40
			(2.40)	(2.30)		(1.13)	(1.09)

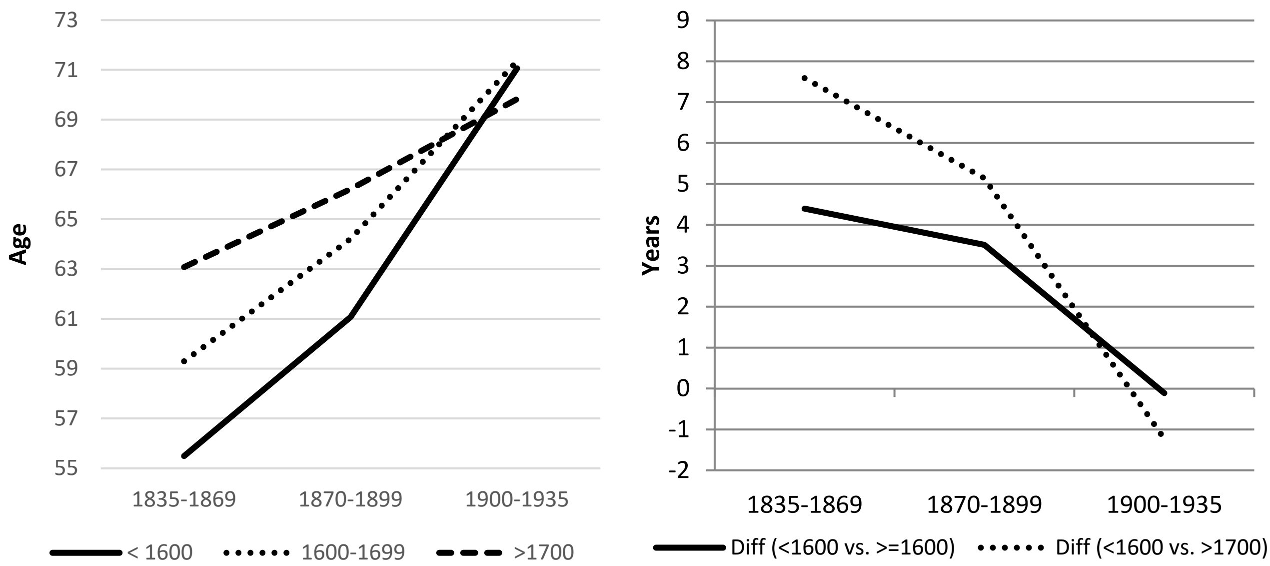
Intercept	45.72***	47.33***	43.06***	79.26***	77.95***	76.57***
Control Cause of death	NO	NO	YES	NO	NO	YES
Control village	NO	NO	YES	NO	NO	YES
Control birth decade	NO	NO	YES	NO	NO	YES
N	518	518	518	970	970	970
R-sq	0.01	0.10	0.23	0.01	0.07	0.17

Notes: OLS estimates; *se* denotes robust standard error. (++) For the subperiod 1835-1869 the quintiles remain: Q1. <=1560; Q2. >1560 & <=1600; Q3. >1600 & <=1625; Q4. >1625 & <=1665; Q5. >1665. For the subperiod 1870-1899 the quintiles remain: Q1. <=1585; Q2. >1585 & <=1616; Q3. >1616 & <=1649; Q4. >1649 & <=1684; Q5. >1684. For the subperiod 1900-1939 the quintiles remain: Q1. <=1595; Q2. >1595 & <=1633; Q3. >1633 & <=1665; Q4. >1665 & <=1700; Q5. >1700.
Source: Parish registers, censuses and conscription and call-up records; historical municipal and parish archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).
* Statistical significance at 10% level.
** Statistical significance at 5% level.
*** Statistical significance at 1% level.

Figure 4 presents the results of the bivariate analysis between height and life span. We have grouped the individuals according to their date of birth (1835-1869, 1870-1899 and 1900-1935) and into three height groups: a) below 160.0 cm; b) between 160.0 cm and 169.9 cm; and c) 170 cm or more. Having confirmed the existence of a historical relationship between height and life span, the aim of this figure is to test the evolution of this relationship during the period of economic and modernisation. The Figure clearly shows that, as in Table 5, there was a strong positive correlation between life span and height. However, this relationship tends to disappear during the first third of the twentieth century. Among the birth cohorts of 1835-1869, the difference in life span between those under 160 cm and those over 170 cm was 7.6 years, which implies that tall people (over 170 cm) had a 12 percent longer life span. If we compare those under 160 cm with those over 160 cm we find a difference of 3.8 years (an extra 6 percent of life span). For the birth cohorts of 1870-1899, the gap was reduced to 5.1 years (7.7 percent longer life) and

3.1 years (4.7 percent), respectively. The values converge completely for the birth cohort of 1900-1939 and the average age at death increased to over 70 years.

Figure 4. Average life span according to height group and birth date, and average gap in life span depending on height group, birth cohorts 1835-1939



Source: Parish registers, censuses and conscription and call-up records; historical municipal and parish archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

5. DISCUSSION

For this research, height is used as a proxy of early life conditions and other socio-economic, family and health variables that have collapsed into it. For this reason, we have first analysed the socioeconomic, environmental and family determinants of height in our study area. The statistical analysis of height determinants confirms, in the same way as other studies, that there is a relationship between the occupational category of the father and the biological well-being of his children (Alter et al., 2004b; De Beer, 2004; Blum, 2011; López-Alonso, 2012; Schoch et al., 2012). The findings show that conscripts with one parent in the lowest socioeconomic level (day-labourers and low skill employees) were those with the lowest levels of biological well-being. They were, on average, 0.1 cm shorter than the artisans' sons, 1.9 cm smaller than the farmers' sons, and 1.8 cm shorter than the upper-class fathers' sons. These results show that owning cultivated land and having control over production were positive factors in the biological well-being of children. Other factors linked to the biological well-being, such as literacy and health status, are also confirmed to be linked to height, as previous Spanish research has shown (Quiroga, 2003; Martínez-Carrión and Puche, 2009; Ayuda and Puche, 2014; Cámara et al., 2019). However, not all variables have behaved as expected. The results present little evidence in confirming the resource dilution hypothesis. The results seem to indicate the existence of a relationship between a higher number of living siblings and shorter height (although not all results are significant). These findings are contrary to the results obtained in a nearby area where no such dissolution was occurring (Ramon-Muñoz and Ramon-Muñoz, 2017). Because of this controversy, further Spanish studies are needed with a larger sample size to confirm whether there is a difference between rural Spain and the area around the city of Barcelona.

Once we have analysed which factors are correlated with height at age 21, we have performed several statistical analyses with regressions to find the relationship between height and age at death. According to the studies carried out, gains in mean population height are associated with lower mortality in middle and older ages in countries with reliable mortality data (NCD-RisC, 2016). Our analyses confirm the results obtained in previous papers (Waaler, 1984; Fogel, 1994; Baten and Komlos, 1998; Smith et al., 2000; Costa, 2004; Alter et al., 2004a; Thompson et al., 2020), establishing a strong correlation between increasing heights and increasing life spans. In fact, life span increased on average by 3 years between individuals with a height of 150 cm and those of 160 cm, and almost 4 years in the case of individuals of 170 cm. Other socioeconomic factors, such as occupation, could have also affected the average age at death. Likewise, the data obtained showed that the Spanish Civil War and the long post-war period had a negative effect on the average life span, explained above all by nutrition problems. Epidemic outbreaks also had negative effects, reducing average life spans. At the family level, we have analysed the effect of the number of living relatives residing in the same village at the time of the conscript's death. This variable is useful for learning about the effect of the care provided by these relatives on life span. The results show in all cases (at 90% of significant) that the individuals with large families were those with the lowest life span. On the one hand, individuals who died relatively young were more likely to have had many relatives who were still alive. On the other hand, individuals with many relatives generally come from families with many members, which could be related to greater competition for family resources. In this sense, parents with large families may have been forced to increase their workload in order to financially support their families, which may have long-term biological consequences (Horrell et al., 1998).

In Table 6 we replicated some previous models but differentiating between those who died before the age of 65 and those who died later. The results show that the relationship between height and age at death is consistent just for those who died before the age of 65. These results could reinforce the idea of a connection between bad early life conditions and negative outcomes in infant and adult mortality (Smith et al., 2009; Bengtsson and Broström, 2009; Bengtsson and Mineau, 2009). These pernicious effects manifested themselves relatively early in a context of hard manual agricultural labour. Some of the individuals affected by these negative early life conditions ended up dying before the age of 65, without reaching an old age. From the age of 65 onwards, most of the conscripts (engaged in manual labour) suffered from the ailments of age independently of the early life conditions, so that the importance of the height variable seems to have diminished.

Individuals aged 65 and over only show (with significance at 90%) a "shortness penalty" affecting the shortest conscripts, and not in all models. In any case, further research with larger samples is needed to confirm these patterns, given that the resulting sub-sample in no case exceeds 1,000 individuals for more than 100 years of birth cohorts.

In our results, especially for those under 65 years of age, we could be looking at a 'shortness penalty', as noted throughout the article, or a 'tallness premium'. Table 5 and Table 6 show that shortest individuals were negatively affected in their lifespan compared to individuals of intermediate stature. These results are stable in almost all models, so we can identify the existence of a ‘shortness penalty’. However, in the results of some of the regressions used, we also observe that the tall individuals had slightly (and significantly at 90%) longer lifespans than the intermediate individuals. So there could also be a 'tallness premium'. However, the results as a whole are not concise about the existence of this premium.

Finally, Figure 4 with a bivariate analysis has allowed us to check the evolution over time of the relationship between height and age at death. We have been able to verify that there was a convergent trend consistent with the positive evolution of living standards in Spain. During this period there were significant improvements in health and nutritional conditions which contributed to close the anthropometric gap and increasing the average adult life span of the whole population from around 55 to over 80 years (Cussó, 2005; Nicolau, 2005; Spijker et al., 2012; Pérez Moreda et al., 2015). In our sample, during the very late twentieth and early twenty-first centuries, the average age at death of the short men was higher than that of the talls. Therefore, our results are compatible with contemporary studies that found a slightly longer life expectancy among short individuals (Samaras and Elrick, 2002; Samaras, 2012; He et al., 2014). These studies point to the possible existence of small differences in causes of mortality between talls (higher mortality from certain cancers) and shorts (higher mortality from circulatory diseases). We have not found significant differences in causes of death in Table A4 of the appendix but this is possibly a consequence of the small sample size.

In the introduction we referred to the psychological scarring effects that could be conditioning our results. Fundamentally, short individuals could have presented a self-destructive behaviour due to their worse social position and their higher rate of singleness compared to higher individuals. However, the available results cannot confirm this hypothesis. The similarities in causes of death between tall and short individuals, the negative effect of a high number of relatives, the socioeconomic status of the father, their own socioeconomic status and the impact of the Spanish Civil War seem to indicate that early life conditions and the excessive workload of the individuals played a decisive role in the age of death. In any case, it cannot be ruled out that psychological effects also played some role. Wage differences, which may have conditioned the diet in the early stages of the analysis, may have had an effect on the results. Shorts may have been forced to work harder for the same wages as the high earners or have a less adequate diet which in the long run affected their health. However, in the absence of wage and time-worked data for the study area, we cannot draw such a conclusion. A further review of this relationship with wage and workload data in this or another study area is still needed.

6. CONCLUSIONS

This article has studied the relationship between adult height and age at death in the long term. For this purpose, we have analysed the case of 1,488 conscripts from rural Spain born between 1835 and 1939. From these data we have performed different analyses. The first OLS group of analyses enabled us to establish some of the determinants of height and biological well-being. The results obtained show that height is not only determined by genetics, but also by socioeconomic variables such as the father's occupation or literacy were determining factors of height. Our findings also show that the conscripts who claimed to suffer from physical problems in order to legally avoid military service (and were accepted by the authorities) were much shorter than individuals who did not request exemption. This result confirms that having good health has a positive influence on biological well-being.

In the second OLS group of analyses we studied some of the determinants of life span in adulthood. In these analyses, height is shown to be an important factor for the whole study period. The main differences are at the shorts with respect to the intermediate group. With the results obtained we can point out that historically there has been a causal relationship between height, used as a proxy for living and environmental conditions from infancy onwards, and age at death. However, this relationship is not confirmed in the same way for all age-at-death groups. As we have analysed in Table 6, this relationship is especially important for individuals who died before the age of 65. From the age of 65 onwards, this relationship became less important or even disappeared. Possibly, the effect of poor early life conditions on mortality outputs was more visible at younger ages, when individuals with good early life conditions were less likely to die. After the age of 65, when health status deteriorated for most individuals, height was no longer a good predictor of mean age at death.

In addition to the results obtained in the regression models, we have outlined the evolution of the life span in relation to height using descriptive statistics. Our results confirm that the average life span in relation to height has converged over the generations analysed. Among the conscripts born between 1835 and 1869, in a period of high infant mortality, there was an average difference of 7.6 years in life span between those measuring less than 160 cm and those measuring more than 170 cm. In contrast, since the beginning of the twentieth century, already in a phase of declining infant mortality and improving general living conditions, we have found similar life spans for all height groups. Therefore, the correlation between height and age at death ceased to exist for those born from the twentieth century onwards.

We believe that the results obtained in this study may be important in ways that go beyond providing historical knowledge. For example, the negative relationship between short height and a short life span (and vice versa) could still have important consequences in developing countries. In this sense, to know the existence of this relationship could be useful to better guide public health policies in less developed countries or regions. The results obtained in this study have demonstrated the relationship between height and age at death, as well as the influence of demographic conditions on biological well-being. However, given the limited sample size, the results must be confirmed with new analyses for other samples and areas.

BIBLIOGRAPHY

Akachi, Y., Canning, D. 2007. The height of women in sub-Saharan Africa: the role of health, nutrition, and income in childhood. Ann. Hum. Biol. 34 (4), 397-410.

Alter, George. 2004. Height, frailty, and the standard of living: modelling the effects of diet and disease on declining mortality and increasing height, Population Studies 58(3): 265-279.

Alter, G., Neven, M., & Oris, M. 2004a. Height, wealth and longevity in xixth century east Belgium. Ann.Dem. Hist. 108, 19-37.

Alter, G., Neven, M., Oris, M. 2004b. Stature in transition. A micro-level study from nineteenth-century Belgium. Soc. Sci. Hist. 28 (2), 231-247.

Alter, George and James C. Riley. 1989. Frailty, sickness, and death: models of morbidity and mortality in historical populations, Population Studies 43(1): 25 –45.

Ayuda, M.I., Puche-Gil, J. 2014. Determinants of height and biological inequality in Mediterranean Spain, 1859-1967. Econ. Hum. Biol. 15, 101-119.

Baten, J., Komlos, J. 1998. Height and the Standard of Living. *J. Econ. Hist.* 58, 866-870.

Bengtsson, T., & Broström, G. (2009). Do conditions in early life affect old-age mortality directly and indirectly? Evidence from 19th-century rural Sweden. Social Science & Medicine, 68(9), 1583-1590. doi: 10.1016/j.socscimed.2009.02.020

Bengtsson, T., & Mineau, G. P. (2009). Early-life effects on socio-economic performance and mortality in later life: A full life-course approach using contemporary and historical sources. Social Science and Medicine 68(9), 1561-1564.

Black, Robert E., Lindsay H. Allen, Zulfiqar A. Bhutta, Laura E. Caulfield, Mercedes de Onis, Majid Ezzati, Colin Mathers, and Juan Rivera. 2008. Maternal and child undernutrition: global and regional exposures and health consequences, The Lancet 371(9608): 243 –260.

Blum, M. 2011. Government decisions before and during the First World War and the living standards in Germany during the drastic natural experiment. Explor. Econ. Hist. 48, 556-567.

Blum, M. 2013a. The influence of inequality on the standard of living: worldwide anthropometric evidence from the 19th and 20th centuries. Econ. Hum. Biol. 11 (4), 436-452.

Blum, M. 2013b. War, food rationing, and socioeconomic inequality in Germany during the First World War. Econ. Hist. Rev. 66 (4), 1063-1083.

Bogin, B. 2001. The Growth of Humanity, New York, Wiley-Liss.

Bogin, B., Varea, C., Hermanussen, M. Scheffler Ch. 2018. Human life course biology: A centennial perspective of scholarship on the human pattern of physical growth and its place in human biocultural evolution. Am. J. Phys. Anthropol. 165, 834-854.

Bozzoli, C., A. Deaton, and C. Quintana-Domeque. 2009. Adult height and childhood disease, Demography 46 (4): 647 –669.

Cámara, A.D., Martínez-Carrión, J.M., Puche, J., Ramon-Muñoz, J.M., 2019. Height and inequality in Spain: a long-term perspective. Rev. Hist. Econ. 37 (2), 205-238.

Cañabate J, Martínez-Carrión JM (2018) Crisis nutricional y brecha social en la España de la autarquía. U estudio de caso a partir de la talla adulta. Nutr Hosp 35(Extra-5):108-115.

Case, A, Paxson, C. 2008. Stature and status: height, ability, and labor market outcomes. Journal of Political Economy. 116, 499-532.

Collantes, F., Pinilla, V. 2004. Extreme Depopulation in the Spanish Rural Mountain Areas: a case study in Aragon in the 19th and 20th centuries, Rural Hist. 15 (2), 149-166.

Collantes, F., Pinilla, V. 2011. Peaceful Surrender: The Depopulation of Rural Spain in the Twentieth Century. Cambridge Scholars Publishing, Cambridge, UK.

Costa, D. L. (2004). The Measure of Man and Older Age Mortality: Evidence from the Gould Sample. J. Ec. Hist. 64 (1), 1-23.

Craig, L. (2014): Nutrition, the Biological Standard of Living, and Cliometrics. In: Diebolt C, Haupert M (eds) Handbook of Cliometrics. Springer-Verlag, Berlin, pp. 1153-1171.

Cutler, D., Miller, G. 2005. The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States. Demography. 42, 1-22.

Cussó, X. 2005. El estado nutritivo de la población española, 1900-1970. Análisis de las necesidades y disponibilidad de nutrientes. Hist. Agr. 36, 329-358.

De Beer, H. (2004): Observations on the history of Dutch physical stature from the late-Middle Ages to the present, Ec. Hum. Biol. 2, 45-55.

Deaton, Angus. 2007. Height, health, and development, Proceedings of the National Academy of Sciences of the United States of America 104(33): 13232 –13237.

Dixon, P.N., Strano, D.A. (1989). The measurement of inferiority: A review and directions for scale development, Indiv. Psych. 45 (3), 313.

Echeverri, B. 1993. La Gripe Española. La pandemia de 1918-1919. C.I.S., Madrid.

Eveleth, P., Tanner, J. (1990). Worldwide Variation in Human Growth. Cambridge University Press, Cambridge.

Fleury, M., Henry, L. 1956. Des registres paroissiaux à l'histoire de la population: Manuel de dépouillement et d'exploitation d l'état civil ancien. Institut National d'Études Démographiques, Paris.

Floud, R., 2004. The Origins of Anthropometric History. Social Science History 28, 337–343.

Floud, R., Fogel, R.W., Harris, B., Hong, S.C. 2011. The Changing Body: Health, Nutrition, and Human Development in the Western World since 1700. Cambridge University Press, Cambridge, UK.

Floud, R., Fogel, R. W., Harris, B., y Hong, S. C. (Eds.) 2014: Health, mortality and the standard of living in Europe and North America since 1700. Edward Elgar Publishing, Volume I, Cheltenham.

Fogel, R.W., 1986. In Engerman SL, Gallman RE (Eds.), Nutrition and the decline in mortality since 1700: some preliminary findings, Long-term factors in American economic growth. University of Chicago Press, Chicago, pp 439-527.

Fogel, R.W. 1994. Economic growth, population theory, and physiology: the bearing of long-term processes on the making of economic policy. Am. Econ. Res. 84, 369-395.

Galofré-Vilà G (2018) Growth and Maturity: A Quantitative Systematic Review and Network Analysis in Anthropometric History. Econ Huma Biol 28:107-118.

Germán L. 2000. Hacia una tipología del crecimiento económico regional moderno en España. En torno al éxito de las regiones ibéricas. El caso de la provincia de Zaragoza. Ec. Aragonesa 11, 81-98.

Germán, L. 2012. Historia económica del Aragón contemporáneo. Prensas Universitarias de Zaragoza, Zaragoza.

Gjonça, E., & Zaninotto, P. (2008). Blame the parents? The association between parental longevity and successful ageing. Dem. Res. 19, 1435–1449.

Gonzalez-Madrid, D.A., Ortíz-Heras, M., 2017. La dictadura de la miseria La dictadura de la miseria. Políticas sociales y actitudes de los españoles en el primer franquismo. Hist. Soc. 88, pp. 25-46.

Grasgruber, P., Cacek, J., Kalina, T., Sebera, M. 2014. The role of nutrition and genetics as key determinants of the positive height trend. Econ. Hum. Biol. 15, 81-100.

Grasgruber, P., Hrazdíra, E. 2020. Nutritional and socio-economic predictors of adult height in 152 world populations,.Econ. Hum. Bio. 37, 100848.

Guntupalli, A.M., Baten, J. 2006. The development and inequality of heights in north, west, and east India 1915-1944. Econ. Hum. Biol. 43, 578-608.

Hacker, J.D. 2008. Economic, demographic, and anthropometric correlates of first marriage in the mid-nineteenth-century United States. Soc. Sci. Hist. 32 (3), 307-345.

Hatton, T.J. 2011. Infant mortality and the health of survivors: Britain 1910-1950. Economic History Review 62, 951-72.

Hatton, T.J. 2014. How Have Europeans Grown so Tall?, Ox. Econ. Pap.66 (2), 349-372.

Hatton, T.J, Bray, B.E. 2010. Long run trends in the heights of European men, 19th-20th centuries. Econ. Hum. Biol. 8 (3), 405-413.

He, Q., Morris, B.J., Grove, J.S., Petrovitch, H., Ross, W., Masaki, K.H., Rodríguez, B., Chen, R., Donlon, T.A., Willcox, D.C., Willcox, B.J. 3024. Shorter Men Live Longer: Association of Height with Longevity and FOXO3 Genotype in American Men of Japanese Ancestry. PLoS ONE. 9 (5): e94385.

Hodrick, R.J., Prescott, E.C. 1997. Postwar U.S. Business Cycles: An Empirical Investigation. J Money Credit Bank. 29 (1), 1-16.

Horrell, S., Humphries, J., Voth, H.J. 1998. Stature and relative deprivation: fatherless children in early industrial Britain. Cont. Change 13 (1), 73-115. doi: 10.1017/s0268416098003075.

Klasen, Stephan. 2008. Poverty, undernutrition, and child mortality: some inter-regional puzzles and their implications for research and policy, The Journal of Economic Inequality 6(1): 89-115.

Komlos, J. 1998. Shrinking in a Growing Economy? The Mystery of Physical Stature during the Industrial Revolution, Journal of Economic History 58(3): 779-802.

Komlos, J. 2009. Anthropometric history: an overview of a quarter century of research. Anthropol. Anz. 67 (4), 343-356.

Komlos, J, Baten J. (eds.) (1998). The Biological Standards of Living in Comparative Perspective. Stuttgart, Franz Steiner Verlag.

Komlos, J., Baten, J. 2004. Looking backward and looking forward. Anthropometric research and the development of social science history. Soc. Sci. Hist. 28 (2), 191-210.

Komlos J, Kelly IR (eds) (2016) The Oxford Handbook of Economics and Human Biology. Oxford University Press, Oxford.

López-Alonso, M. 2007. Growth with inequality: living standards in Mexico, 1850-1950. J. Latin Am. Stud. 39 (1): 81-105.

López-Alonso, M. (2012): Measuring Up. A History of Living Standards in Mexico, 1850-1950. Stanford, California, Stanford, University Press.

Luque del Haro, V. 2020. Análisis histórico Del nivel de vida en Andalucía. Desigualdad social y mortalidad: ensayo interpretativo y estudio empírico de un caso en el sureste español. Universidad de Almería. Ph.D. Diss.

McKeown, T. (1976): The modern rise of population, Arnold, London.

Maluquer de Motes, J. (2014): La economía española en perspectiva histórica. Barcelona, Pasado y Presente.

Manfredini, M., Breschi, M., Fornasin, A., Seghieri, C. 2013. Heights, socioeconomic status and marriage in Italy around 1900. Econ. Hum. Biol. 11, 465-473.

Marco-Gracia, F.J. 2017. Influence of the Social and Economic Changes in the Fertility Control: an analysis of rural Spain based on microdata (16^{th}-21^{st} centuries). Universidad de Zaragoza. Ph.D. Diss.

Marco-Gracia, F.J. 2018a. Why did they not get married? Biological, economic and family determinants of celibacy in rural Spain (1785-2010). Invest. Hist. Econ. 14, 140-153.

Marco-Gracia, F.J. 2018b. How was the fertility transition carried out? Analysis of the fertility control strategies and their evolution in rural Aragón, Spain (1880-1955). Hist. Agr. 76, 189-220.

Marco-Gracia, F.J. 2018c. The Genesis of the Second Demographic Transition in Rural Aragon (1970-2012). REIS 161, 63-86.

Marco-Gracia, F.J. 2019. Fertility control due to short-term economic stress in rural Aragón (Spain), 1801-1909. Rev. Hist. Econ. On-line first.

Marco-Gracia, F.J. 2021. "Like Father, Like Son": The Importance of Fathers in Nineteenth- and Twentieth-century Rural Spain. J. Fam. Hist. doi: 10.1177/0363199020986815

Martínez-Carrión, J.M., Cámara, A.D., Pérez-Castroviejo, P.M. 2016. Parámetros antropométricos de los reclutas españoles antes de la transición nutricional. Análisis de las desigualdades territoriales (1858-1913). Nutr. Hosp. 33 (6), 1477-1486.

Martínez-Carrión, J.M., Moreno-Lázaro, J. 2007. Was there an urban height penalty in Spain, 1840-1913? Econ. Hum. Biol. 5, 144-164.

Martínez-Carrión, J.M., Puche-Gil, J. 2009. Alfabetización, bienestar biológico y desigualdad: la Comunidad Valenciana, 1850-1970. Hist. Agr. 47, 167-186.

Martorell R. 2010. Physical growth and development of the malnourished child: contributions from 50 years of research at INCAP. Food and nutrition bulletin 31(1), 68-82.

McEvoy, B.P, Visscher, P.M. 2009. Genetics of human height. Econ. Hum. Biol.7, 294-306.

Moradi, Alexander. 2010b. Nutritional status and economic development in Sub-Saharan Africa, 1950 –1980, Economics & Human Biology 8(1): 16 –29.

Murasko, J.E. 2020. Height, Marriage, and Partner Characteristics for Women in Low-and Middle-income Countries. Econ. Hum. Biol. 100876.

NCD-RisC. 2016. A century of trends in adult human height. eLife. 2016. DOI: 10.7554/eLife.13410

NCD-RisC. 2020. Height and body-mass index trajectories of school-aged children and adolescents from 1985 to 2019 in 200 countries and territories: a pooled analysis of 2181 population-based studies with 65 million participants. Lancet.396, 1511-1524.

Nicolau, R. 2005. Población, salud y actividad. In Carreras, A., Tafunell, X. (Eds.), Estadísticas Históricas de España. FBBVA, Barcelona, pp. 77-154.

Núñez, C.E. 2005. Educación. In Carreras, A., Tafunell, X. (Eds.), Estadísticas Históricas de España. FBBVA, Barcelona, pp. 157-244.

Öberg, S. (2017): Too many is not enough: studying how children are affected by their number of siblings and resource dilution in families, The History of the Family 22(2-3), pp. 157-174.

Ortega, J.A., Silvestre, J., 'Las consecuencias demográficas', in P. Martín Aceña and E. Martínez Ruiz, eds., La economía de la guerra civil (Madrid, 2006), pp. 53-105.

Peiró, A. 1987. El mercado de cereales y aceite aragoneses (siglos XVII-XX). Agr. & Soc. 43, 213-241.

Pérez-Moreda, V., Reher, D.S., Sanz Gimeno, A., 2015. La conquista de la salud. Mortalidad y modernización en la España contemporánea. Marcial Pons, Madrid.

Perkins, J.M., Subramanian, S.V., Davey Smith, G., Özaltin, E. 2016. Adult height, nutrition and population health. Nutr. Rev. 74(3), 149-165.

Peracchi, F., Arcaleni, E. 2011. Early life environment, height and BMI of young men in Italy. Econ. Hum. Biol. 9, 251-264.

Prados de la Escosura, L., 2017. Spanish Economic Growth, 1850–2015. London: Palgrave Macmillan.

Preston, S.H., Haines, M. (1991): Fatal Years: Child Mortality in Late Nineteenth Century America, Princeton, Princeton University Press.

Puell de la Villa, F. (1996): El soldado desconocido: de la leva a la 'mili' (1700-1912), Madrid, Biblioteca Nueva.

Puche-Gil, J. 2009. Evolución de los niveles de vida biológicos en la Comunidad Valenciana, 1840-1948. Universidad Pablo de Olavide de Sevilla. Ph.D. Diss.

Puche-Gil, J. 2011. Evolución de los niveles de vida biológicos en la Comunidad Valenciana, 1840-1948. Invest. Hist. Econ. 21, 380-394.

Quintana-Domeque, C., Bozzoli, C., Bosch, M. 2012. The evolution of adult height scross Spanish regions, 1950-1980. Econ. Hum. Biol. 10, 264-275.

Quiroga, G. 2001. Estatura, diferencias regionales y sociales y niveles de vida en España (1893-1954). Rev. Hist. Econ. 19, 175-200.

Quiroga, G. 2003. Literacy, education and welfare in Spain (1893-1954). Paed. Hist. 39 (5), 599-619.

Ramón Muñoz, J.M. 2011. Industrialización, urbanización y bienestar biológico en Cataluña, 1840-1935: una aproximación antropométrica. Rev. Hist. Ind. 46, 41-71.

Ramón Muñoz, R., and Ramón Muñoz, J. M. 2017. Sibship Size and the Biological Standard of Living in Industrial Catalonia, c. 1860–c. 1920: A Case Study.The History of the Family 22(2–3), 333–363.

Reher, D., González-Quiñones, F. 2003. Does parents really matter? Child health and development in Spain during the demographic transition. Pop. Stu. 57 (1), 63-75.

Salvatore, R.D., Coasworth, J.H., Challú, A.E. (Eds.), 2010. Living Standards in Latin American History: Height, Welfare and Development, 1750-2000. Harvard University David Rockefeller Center for Latin American Studies, Cambridge, MA.

Samaras, T.T., Elrick, H. 2002. Height, body size, and longevity: is smaller better for the humanbody? West J. Med. 176(3), 206-208.

Samaras, T. T, (2012). How height is related to our health and longevity: A review. Nutrition and Health 21(4), 247-261.

Schick, A., Steckel, R.H. 2015. Height, Human Capital, and Earnings: The Contributions of Cognitive and Noncognitive Ability. Journal of Human Capital. 9(1), 94-115.

Schmidt, I.M., Jørgensen, M.H., Michaelsen, K.F. 1995. Height of conscripts in Europe: is postneonatal mortality a predictor? Annals of Human Biology, 22, 57-67.

Schneider, E. 2020. Collider Bias in Economic History Research (SSRN Scholarly Paper ID 3638045). Social Science Research Network. https://papers.ssrn.com/abstract=3638045.

Schoch, T., Staub, K., Pfister, C.H. 2012. Social inequality and the biological standard of living: an anthropometric analysis of Swiss conscription data, 1875-1950. Econ. Hum. Biol. 10, 154-173.

Sear, R., 2010. In Frey, U., Störmer, C., Willführ, K.P. (Eds.), Height and reproductive success, Homo novus-A human without illusions, Springer, pp. 127-143.

Silventoinen, K. 2003. Determinants of variation in adult body height. J. Bios. Sci. 35, 263-285.

Silvestre, J. 2005. Internal migrations in Spain, 1877-1930. Eur. Rev. Econ. Hist. 9 (2), 233-265.

Smith, G. D., Hart, C., Upton, M., Hole, D., Gillis, C., Watt, G., & Hawthorne, V. (2000). Height and risk of death among men and women: Aetiological implications of associations with cardiorespiratory disease and cancer mortality. J. Epid. Com. Health. 54, 97-103.

Smith, K., Mineau, G., Garibotti, G., and Kerber, R. (2009). Effects of childhood and middle-adulthood family conditions on later-life mortality: Evidence from the Utah Population Database, 1850–2002. Social Science & Medicine, 68(9), 1649-1658. doi: 10.1016/j.socscimed.2009.02.010

Sohn, K. 2015. The value of male height in the marriage market. Econ. Hum. Biol. 18, 110-124.

Spijker, J., Cámara, A.D., Blanes, A. 2012. The health transition and biological living standards: adult height and mortality in considerably-century Spain. Econ. Hum. Biol. 10, 276-288.

Steckel, R.H. 2008. Biological measures of the standard of living, J. Econ. Perspect. 22 (1): 129-152.

Steckel, R.H. 2009. Heights and human welfare: recent developments and new directions. Explor. Econ. Hist. 46 (1), 1-23.

Steckel R.H. (2019). Anthropometrics. In: Diebolt C, Haupert M (eds) Handbook of Cliometrics. Springer-Verlag, Berlin, pp. 1153-1171.

Szreter, S. 1988. The importance of social intervention in Britain´s mortality decline, 1850-1914: a reinterpretation of the role of public health. Social History of Medicine 1, 1-38.

Tanner, J.M. (1981): A history of the study of human growth. New York, Cambridge University Press.

The Emerging Risk Factors Collaboration. 2012. Adult height and the risk of cause-specific death and vascular morbidity in 1 million people: individual participant meta-analysis. International Journal of Epidemiology. 41, 1419-1433.

Thompson, K., Quanjer, B., Murkens, M. 2020. Grow fast, die young? The causes and consequences of adult height and prolonged growth in nineteenth century Maastricht, Social Science & Medicine, online first. DOI: j.socscimed.2020.113430

Van den Berg, N., Rodríguez-Girondo, M., Van Dijk, I. K., Mourits, R. J., Janssens, A., Mandemakers, K., Beekman, M., Smith, K. R., & Slagboom, P. E. (2019). Longevity defined as top 10% survivors and beyond is transmitted as a quantitative genetic trait. Nature Com. 35, 1–12.

Verdejo Lucas, J.M. (2004): Ejército, política y sociedad en el Reinado de Alfonso XIII, Tesis doctoral, Madrid, Ministerio de Defensa.

Voth, H.J. (2004), "Living standards and the urban environment", in Floud, R. and Johnson, P. (eds.), *The Cambridge Economic History of Modern Britain, Volume I: Industrialisation, 1700-1860*. Cambridge: Cambridge University Press, pp. 268-294.

Waaler, H.T. 1984. Height, weight and mortality: the Norwegian Experience. Acta Med. Scand. 679, 1-56.

APPENDIX

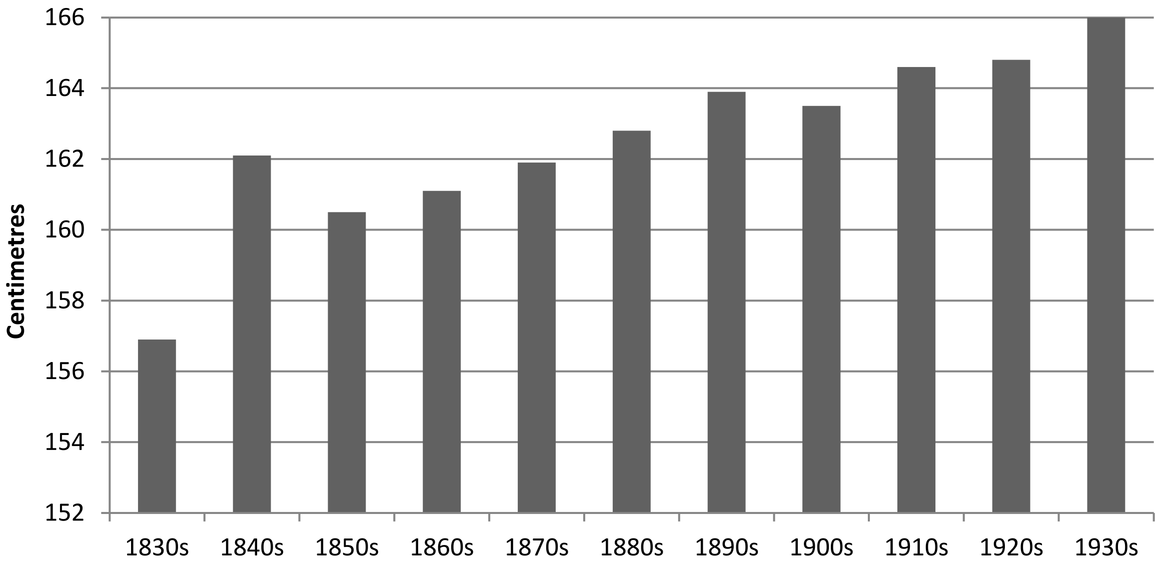


Fig. A1. Average height according to birth decade. Sample: 1,488 heights.

Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

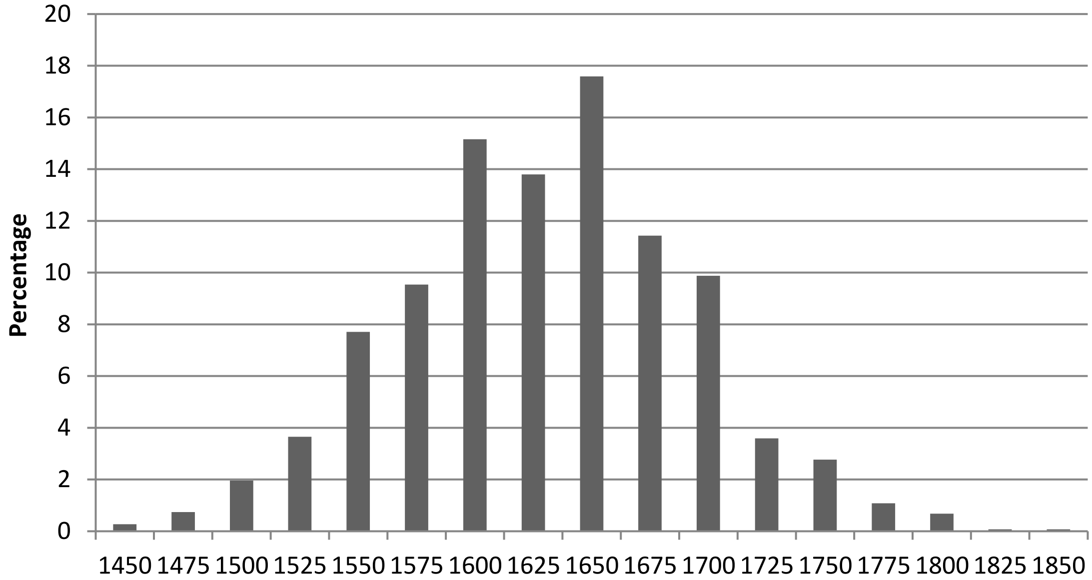


Fig. A2. Distribution of heights in the complete period, birth cohorts 1835-1939. Sample: 1,488 heights. Mean=164.0, Std. Dev. =1.7.

Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

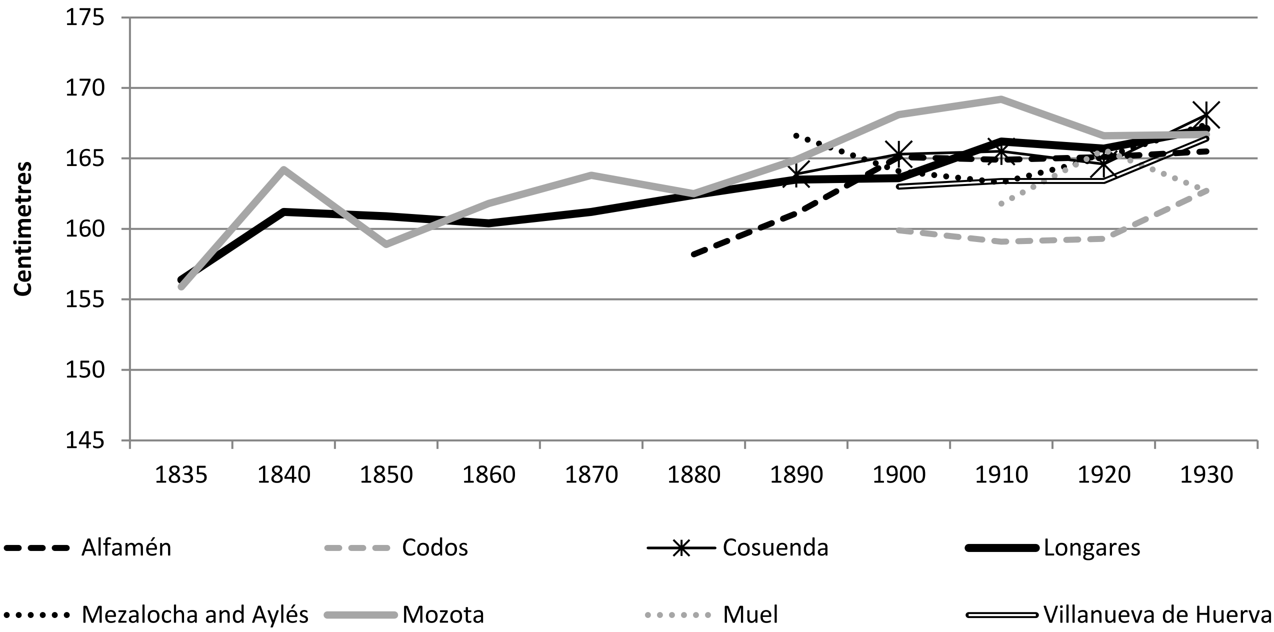


Fig. A3. Comparison of average height according to municipality and decade of birth (period in which data are available in municipal archives).

Note: We have included only municipalities with a height sample over 80 observations. The thickest lines correspond to Longares and Mozota, the municipalities that have a complete period sample.

Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample.

Table A1. Sample characteristics of the first subperiod, birth cohorts 1835-1869. Sample: 190 heights.

	Variables	Cases	%	Average height	SD	Average age at death	SD
Locality of residence	Alfamén	5	2.70	165.2	29.2	69.2	8.6
	Botorrita	3	1.62	174.6	14.5	60.4	12.2
	Jaulín	3	1.62	161.2	36.9	72.7	3.5
	Longares	119	64.32	160.3	5.8	58.5	1.6
	Mozota	36	19.46	161.6	9.5	54.4	3.2
	Muel	13	7.03	159.8	14.2	56.0	4.7
	Tosos	4	2.16	159.2	14.7	57.1	7.2
	Villanueva de Huerva	2	1.62	170.7	22.5	62.2	0.9
Literacy	Illiterate	8	4.32	162.6	33.6	57.9	70.9
	Literate	17	9.19	161.3	16.2	56.9	5.9
	Unknown	160	86.49	160.9	4.8	58.2	1.3
Occupation	Low skills employee	80	43.24	159.9	6.2	55.6	1.8
	Farmer	77	41.62	160.8	7.9	59.1	2.1
	Artisan	14	7.57	164.6	16.8	50.9	4.9
	Upper class	1	0.54	162.6	-	77.1	-
	Other or unknown	13	7.03	164.4	14.8	73.1	2.8
Father's occupation	Low skilled worker	68	36.76	160.2	6.6	57.3	2.1
	Farmer	68	36.76	161.3	8.5	59.9	2.2
	Artisan	18	9.73	162.7	15.7	56.7	4.6
	Upper class	1	0.54	162.6	-	77.1	-
	Others or unknown	30	16.22	160.8	12.0	56.0	3.0

Motherless	No	165	89.19	161.5	5.0	58.8	1.4
	Yes	20	10.81	160.9	13.3	51.9	3.6
Fatherless	No	169	91.35	162.3	4.9	58.3	1.3
	Yes	16	8.65	160.8	14.8	55.6	4.4
Number of living siblings	0 siblings	16	8.65	160.2	14.1	61.9	4.2
	1-2 siblings	22	11.89	161.5	14.5	65.3	2.9
	3-4 siblings	139	75.14	160.9	5.5	55.8	1.5
	5 or more siblings	8	4.32	161.7	20.9	70.6	2.9
Family support at death	0-2 people	96	51.89	160.9	6.3	57.0	1.7
	3-5 people	60	32.43	160.9	8.6	56.5	2.5
	6 or more people	29	15.68	161.2	11.3	64.5	2.6
Physical Appeals	No	150	81.08	161.3	4.8	58.6	1.4
	Yes	16	8.65	157.3	17.6	52.7	4.5
Number of economic crises	0 crises	17	9.19	159.6	14.0	59.5	4.3
	1 crisis	91	49.19	161.3	6.3	57.7	2.0
	2 crises	67	36.22	161.2	8.7	57.3	5.7
	3 crises	10	5.41	158.5	14.2	64.1	5.7
Dying in an epidemic year	Yes	15	8.11	162.6	13.7	59.1	4.6
	No	170	91.89	160.8	4.9	58.0	1.4
Dying during the war and post-war	War (1936-1939)	5	2.70	165.4	31.4	75.1	1.3
	1st post-war (1940s)	15	8.11	158.9	13.6	78.2	1.1
	2nd p-w (1950-1958)	4	2.16	165.8	9.7	82.6	1.1
	No war or post-war	161	87.03	160.9	5.0	55.1	1.3

Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

Table A2. Sample characteristics of the second subperiod, birth cohorts 1870-1899. Sample: 220 heights.

	Variables	Cases	%	Average height	SD	Average age at death	SD
Locality of residence	Alfamén	6	2.68	161.9	24.0	69.3	9.1
	Aylés	3	1.34	165.3	8.8	80.7	5.8
	Botorrita	2	0.89	161.2	42.5	46.4	21.7
	Codos	1	0.45	168.0		74.5	
	Cosuenda	24	10.71	164.1	12.3	62.5	3.6
	Jaulín	1	0.45	163.0		67.0	
	Longares	149	66.52	162.4	4.6	62.3	1.5
	Mezalocha	3	1.34	167.8	13.6	63.3	11.7
	Mozota	20	8.93	164.1	8.9	71.5	2.5
	Muel	8	3.57	163.8	19.7	61.0	3.6
	Torrecilla de Valmadrid	1	0.45	159.5		81.8	
	Tosos	1	0.45	176.0		70.5	
	Valmadrid	2	0.89	166.0	40.0	71.5	2.9
	Villanueva de Huerva	3	1.34	167.8	14.8	61.0	22.7
Literacy	Illiterate	40	17.86	162.9	8.4	65.9	2.5
	Literate	126	56.25	163.7	4.8	64.4	1.7
	Unknown	58	25.89	161.8	7.6	60.6	2.1
Occupation	Low skills employee	118	52.68	162.3	5.2	60.8	1.6
	Farmer	77	34.38	163.2	6.4	64.2	1.9
	Artisan	13	5.80	166.0	4	66.8	6.4
	Upper class	2	0.90	170.5	10.0	76.8	11.1
	Other	14	6.25	165.3	12.0	79.9	2.7
Father's occupation	Low skilled worker	121	54.02	162.7	5.0	61.8	1.6
	Farmer	63	28.13	163.4	7.1	65.2	2.1

	Artisan	13	5.80	166.0	12.6	67.3	5.5
	Upper class	1	0.45	162.0	-	50.7	-
	Other or unknown	26	11.61	162.6	11.5	67.2	3.9
Motherless	No	201	89.73	163.4	3.9	64.1	1.3
	Yes	23	10.27	162.0	11.2	60.3	3.6
Fatherless	No	208	92.9	163.1	3.8	63.6	1.2
	Yes	16	7.14	162.8	13.5	65.0	4.7
Number of living siblings	0 siblings	15	6.70	164.1	10.7	67.8	2.7
	1-2 siblings	47	20.98	163.4	7.8	69.5	2.1
	3-4 siblings	160	71.43	162.9	4.5	61.5	1.5
	5 or more siblings	15	6.70	160.5	75.2	72.2	1.7
Family support at death	0-2 people	71	31.70	163.2	5.3	64.2	1.5
	3-5 people	125	55.80	162.7	5.9	61.0	2.5
	6 or more people	28	12.50	163.1	9.2	68.0	1.9
Physical Appeals	No	180	80.36	163.0	3.7	63.5	1.2
	Yes	11	4.91	164.3	25.0	66.9	5.0
Number of economic crises	0 crises	40	17.86	163.4	7.8	64.9	3.1
	1 crisis	120	53.57	162.4	5.4	61.7	1.5
	2 crises	39	17.41	164.7	7.5	61.9	3.4
	3 crises	25	11.16	163.1	11.2	73.7	2.5
Dying in an epidemic year	Yes	3	1.34	163.0	18.9	33.3	1.2
	No	221	98.66	163.1	3.7	64.1	1.2
Dying during the war and post-war	War (1936-1939)	3	1.34	164.6	19.2	45.9	6.8
	1st post-war (1940s)	38	16.96	161.1	9.2	61.7	1.3
	2nd p-w (1950-1958)	38	16.96	163.4	8.9	68.5	1.4
	No war or post-war	145	64.73	163.4	4.6	63.3	1.7

Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

Table A3. Sample characteristics of the third subperiod, birth cohorts 1900-1939. Sample: 1,078 heights.

	Variables	**Cases**	**%**	**Average height**	**SD**	**Average age at death**	**SD**
Locality of residence	Alfamén	200	18.54	165.1	4.3	70.8	1.2
	Aylés	51	4.73	164.4	11.0	74.2	2.3
	Botorrita	55	5.10	166.9	11.8	71.0	2.3
	Codos	115	10.66	159.9	5.8	71.5	1.6
	Cosuenda	127	11.77	165.3	5.1	68.7	1.6
	Jaulín	35	3.24	166.0	10.3	73.6	3.1
	Longares	204	18.91	165.1	4.0	68.1	1.1
	Mezalocha	48	4.45	165.1	7.9	71.3	2.2
	Mozota	32	2.97	167.4	11.1	67.6	3.5
	Muel	66	6.12	165.3	7.1	72.4	1.9
	Torrecilla de Valmadrid	3	0.28	164.1	7.2	73.0	6.0
	Tosos	30	2.78	166.2	9.9	76.8	2.2
	Valmadrid	4	0.37	166.6	18.4	85.6	2.0
	Villanueva de Huerva	109	10.10	164.0	6.3	74.0	1.6
Literacy	Illiterate	83	7.69	162.8	8.5	70.0	1.9
	Literate	967	89.62	164.8	2.0	71.1	0.5
	Unknown	29	2.69	163.9	13.8	68.2	3.7
Occupation	Low skills employee	507	46.99	164.2	2.9	69.9	0.8
	Farmer	436	40.41	165.3	3.2	71.6	0.8
	Artisan	40	3.71	164.8	10.8	66.7	2.7
	Upper class	13	1.20	167.1	19.1	68.5	7.0
	Other	83	7.69	163.9	5.8	76.4	1.3

Father's occupation	Low skilled worker	537	49.77	164.4	2.8	70.0	0.8
	Farmer	366	33.92	165.4	3.4	72.4	0.8
	Artisan	47	4.36	164.6	10.6	70.8	2.1
	Upper class	13	1.20	166.0	12.1	66.0	4.9
	Other or unknown	116	10.75	163.9	5.8	71.4	1.5
Motherless	No	1,022	94.72	165.6	2.0	70.8	0.5
	Yes	57	5.28	164.6	8.1	73.4	1.9
Fatherless	No	1,012	93.79	164.7	2.0	71.0	0.5
	Yes	67	6.21	164.7	7.7	71.0	2.0
Number of living siblings	0 siblings	68	6.30	165.3	8.4	75.2	1.7
	1-2 siblings	341	31.60	165.4	3.3	75.5	0.7
	3-4 siblings	661	61.26	164.3	2.6	68.2	0.7
	5 or more siblings	9	0.83	163.1	11.2	68.5	3.6
Family support at death	0-2 people	596	55.24	164.2	2.6	71.2	0.7
	3-5 people	311	28.82	165.1	4.0	68.5	1.1
	6 or more people	172	15.94	165.4	4.9	74.8	1.0
Physical Appeals	No	846	78.41	165.0	2.0	71.5	0.5
	Yes	85	7.88	161.2	9.5	65.1	2.3
Number of economic crises	0 crises	204	18.91	164.5	4.8	69.5	1.3
	1 crisis	285	26.41	163.8	3.7	68.9	1.1
	2 crises	74	6.86	165.1	7.4	72.0	2.3
	3 crises	516	47.82	165.1	2.8	72.5	0.6
Dying in an epidemic year	Yes	0	0.00				
	No	1,079	100.00	164.7	2.0	71.0	0.5
	War (1936-1939)	11	1.02	166.6	16.1	26.7	1.2
	1st post-war (1940s)	29	2.69	164.1	11.3	33.1	1.5

Dying during the war and post-war	2nd p-w (1950-1958)	42	3.89	162.4	11.4	40.9	1.6
	No war or post-war	997	92.40	164.7	2.0	73.8	0.4

Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

Table A4. Distribution (percentage) of causes of death according to height group, birth cohorts 1835-1939. Sample: 879 deaths.

Cause of death	**<1600**	**>=1600 & <1700**	**>=1700**
Infectious diseases	3,43	2,7	5,13
Neoplasm (cancer)	10,78	12,91	13,46
Endocrine or blood diseases	1,47	0,96	1,28
Mental disorders	0,98	0,58	0,64
Nervous system	2,94	1,93	1,28
Circulatory system	50,98	53,56	51,28
Respiratory system	13,73	13,1	12,82
Digestive system	8,33	7,13	7,05
Genitourinary system	1,47	3,08	1,92
No classifiable	1,47	0,77	0,64
Injury and other external causes	4,41	3,27	4,49
Number of observations:	204	519	156

Note: Causes of death classified using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10).

Source: Parish records of death; historical parish archives from municipalities composing the anthropometric sample.