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Did taller people live longer? Influence of height on life span in rural Spain, 1835-2019

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Abstract: This article analyses the relationship between male height and age at death among adults born between 1835 and 1939 in fourteen villages in north-east 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; demographic and socioeconomic data 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 that there has been 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 individuals measuring less than 160 cm. This biological difference disappeared for the birth cohort of 1900-1939 due to a progressive improvement in health and nutrition conditions, benefiting especially the short conscripts.

Keywords: Heights; Life span; Biological inequality; rural Spain; 1835-2019

1. Introduction

The study of the historical evolution of the living standards of populations is a central theme of historiography (Voth, 2004; Salvatore et al., 2010; Floud et al., 2011, 2014; Komlos and Kelly, 2016). In this regard, we can highlight the studies that use demographic variables such as life expectancy or child mortality rates (Floud et al., 2011, 2014). However, these approaches only allow an analysis of the group level.

Over the last four decades, an increasing number of studies have been conducted on a new group of indicators of biological wellbeing at the individual and group level, using anthropometric measurements and biological wellbeing indexes, such as height, weight and body mass index (Steckel, 2008, 2019; Silventoinen, 2003; Komlos and Baten, 2004; Komlos, 2009; Komlos and Kelly, 2016; NCD-RisC, 2020). These variables allow comparisons to be made on an individual level, focusing on anthropometrical, family and socioeconomic characteristics. This field of study, known as anthropometric history, was spearheaded by Robert W. Fogel, awarded with the 1993 Nobel Prize in Economics, and other colleagues (Fogel, 1994; Komlos and Baten, 1998; Floud, 2004). After several decades of research, we are able to establish that height is a good indicator of biological wellbeing of the human 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). Genetics explain approximately 80% of the height of individuals. The remaining 20% is conditioned by various factors such as nutrition, epidemiology or the environment (Silventoinen, 2003; McEvoy and Visscher, 2009; Grasgruber et al., 2014; Hatton, 2014).

In recent decades, part of anthropometric research has focused on the study of the determinants of height and biological inequality using socio-economic variables (Silventoinen, 2003; Guntupalli and Baten, 2006; Akachi and Canning, 2007; López-Alonso, 2007; Steckel, 2009; Schoch et al., 2012; Hatton, 2014; Blum, 2013a; Ayuda and Puche-Gil, 2014). Another perspective using anthropometric data is the study of the effects of height on demographic events occurring after conscription. For example, several studies have demonstrated a connection between height and the likelihood of marrying (for USA: Hacker, 2008; for Italy: Manfredini et al., 2013; for Indonia: Sohn, 2015; for Spain: Marco-Gracia, 2018a; for a summary: Murasko, 2020). Other studies have focused on the relationship between height and the life span of adults (or life expectancy).[1] The possibility of this relationship was emphasised by Fogel (1994) during his Nobel Prize lecture. 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 and height and occupation 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. Other authors who have worked with recent data find that short individuals have some health and longevity advantages (Samaras and Elrick, 1999; Samaras, 2012). Genetic factors are also strongly correlated with longevity (Gjonça and Zaniotto, 2008; Van den Berg et al., 2019). However, there is no evidence of a direct relationship between genes linked to higher stature and genes linked to longevity.

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.

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, their families and their life trajectory. The period of study, that is, the, birth cohorts of 1835-1939, partly coincided with the Spanish economic and social modernisation process of 1850-2000 (Nicoalu, 2005; Maluquer de Motes, 2014; Pérez Moreda et al., 2015; Prados de la Escosura, 2017).

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 con-

[1] We use the term 'life span' as an indicator of the exact duration of the life. We use 'life expectancy' as an indicator of the average time a person is expected to live.

scripts. Similarly, 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.

This study provides a qualitative leap on several levels. First, it studies the relationship between height and life span over the very long-term, for individuals born over 100 years ago. Second, it provides new evidence regarding the influence of the environmental context and socioeconomic variables both on biological welfare and on the individual's life span. Third, it 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). Finally, there is very little literature on this issue in the very long-term. We have included information on death from the nineteenth century to 2019.

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). The population mostly lived in nuclear households and worked, on the whole, 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 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).

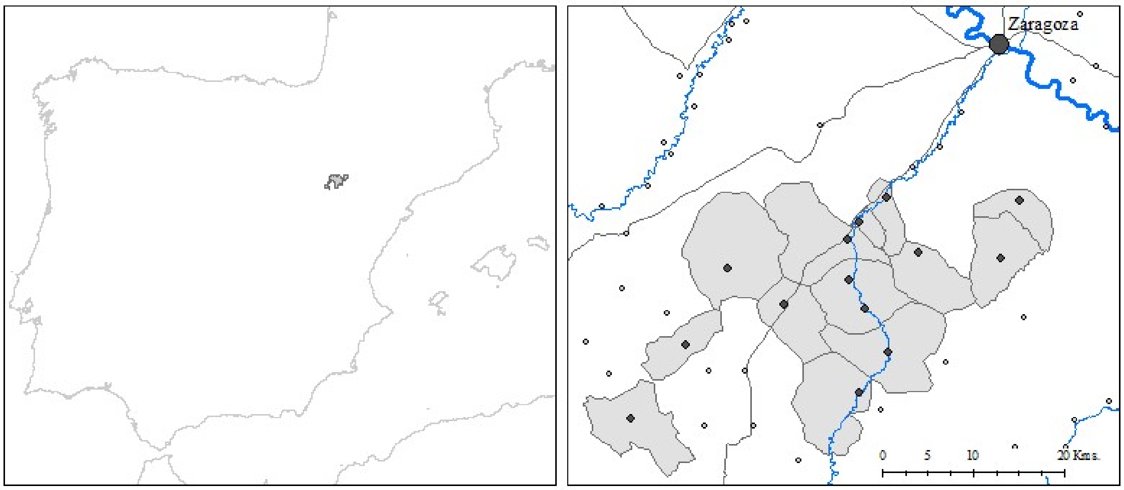

Figure 1. Area of study: Middle Huerva (Aragón, Spain); Source: Own elaboration. Note: Dark dots indicate the villages studied (except Zaragoza, the provincial capital) and the corresponding shaded areas refer to their municipal boundaries.

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. Mortality rates began to decline in the last third of the nineteenth century due to the progressive advance of the epidemiological transition (Marco-Gracia, 2017). Anthropometric evidence also indicates that biological standards of living 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 2020).

This study covers a period from approximately the middle of the nineteenth century to the first decades of the twenty-first century. During this long period Spain experienced a significant improvement in its living and health conditions. Figure 2 shows the consequences of these improvements on the evolution of height and life expectancy in the area studied. According to Figure 2, life expectancy has increased from less than 20 years to more than 80 years in the last 150 years. The average height at death has also increased by almost 10 centimetres in the same period as a result of these improvements.

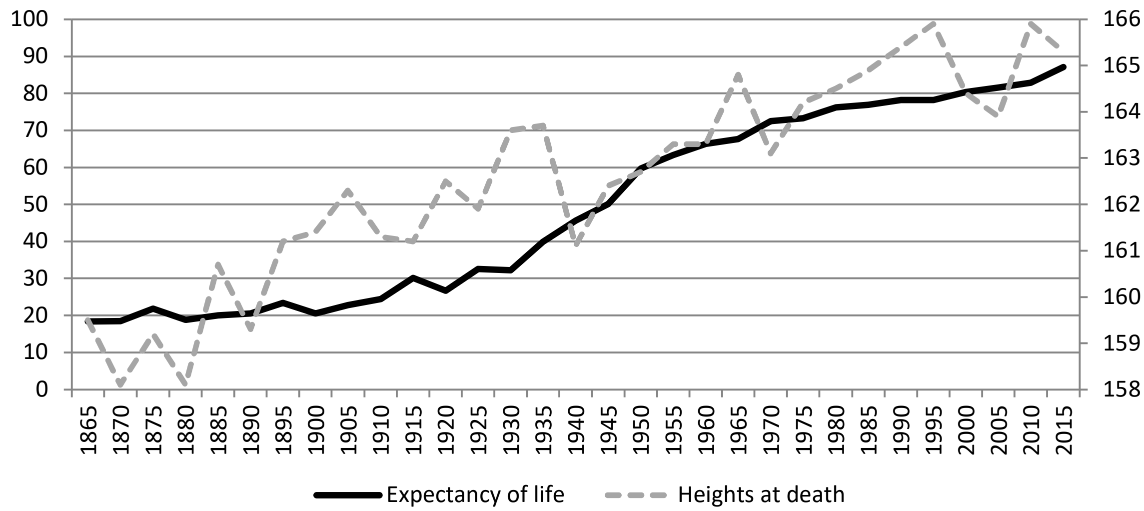

Figure 2. Life expectancy and heights (according to date of death) in the area of study, 1860-2019. Notes: In the figure we compare the evolution of the average age at death and height of the men that died in that period (we have information about their height) every five years. To see the comparison of average height according to municipality and decade of birth (period in which data are available in municipal archives) see Figure A2 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

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 data from sources linked to cemeteries (recent years); 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. During the period analysed, the age of conscription varied over time.[2] 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. 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. A1), although we can observe some imperfections due to the low sample size, and the age-heaping tendency exercised by rural doctors. We have tested the null

[2] 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.

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 (alfamen@dpz.es), Botorrita (botorrita@dpz.es), Codos (codos@dpz.es), Cosuenda (cosuenda@dpz.es), Jaulín (jaulin@dpz.es), Longares (longares@dpz.es), Mezalocha (mezalocha@dpz.es), Mozota (mozota@dpz.es), Muel (muel@dpz.es), Tosos (tosos@dpz.es), Villanueva de Huerva (vhuerva@dpz.es), Historical archive of Zaragoza –for the data of Torrecilla de Valmadrid- (archivo@zaragoza.es), and Historical Military Archive of Guadalajara (agm_guadalajara@et.mde.es).

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.[3] 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.[4] 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[5], linking them to population records for each individual.

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

During the twentieth century there was progressive migration from rural to urban areas (Silvestre, 2005). In the 1960s, for example, 5.7 million people changed their residence (Nicolau, 2005; Collantes and Pinilla, 2011). These migrations condition 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). In Table 3 we can observe the distribution of our sample for several variables, including the average height and average life span.

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	599	40.26	163.8	2.7	63.7	0.8
	Farmer	261	17.54	164.5	4.1	67.7	1.1
	Artisan	56	3.76	164.9	7.9	62.1	2.7
	Upper class	16	1.07	167.0	14.5	63.4	6.1
	Other	556	37.37	163.7	2.6	74.1	0.5
	Low skills employee	480	32.26	163.6	3.0	67.0	0.8

Father's occupation	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	11.0	65.8	4.4
	Other or unknown	418	28.09	163.7	3.0	68.3	0.9
Family size (including parents)	0-4 people	715	48.05	163.5	2.4	70.5	0.6
	5-6 people	615	41.33	164.1	2.6	66.6	0.7
	7 or more people	158	10.62	165.4	5.3	64.8	1.7
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
Appeals for exemption	No appeal (fit to serve)	1,176	79.03	164.2	1.8	68.5	0.5
	Physical appeals	112	7.53	161.0	8.1	63.5	2.0
	Social appeals	200	13.44	164.4	4.5	69.5	1.1
Dying in an epidemic year	Yes	1,470	98.79	162.7	11.7	54.8	4.6
	No	18	1.21	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
Number of economic crises experienced (after age 21)	Zero	47	3.16	164.4	9.3	34.4	2.3
	One	113	7.59	164.0	7.0	49.9	1.8
	Two	123	8.27	164.5	5.8	60.1	1.5
	Three	131	8.80	164.3	5.6	61.8	1.5
	Four	240	16.13	164.3	4.3	70.7	0.9
	Five	127	8.53	163.7	5.7	72.3	1.4
	Six or more	707	47.51	163.7	2.3	74.5	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).

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 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 welfare. 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.

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. In the area of study, traditionally almost 80% of individuals had been employed in agrarian occupations, as day-labourers or farmers (Marco-Gracia, 2018b). Due to the particular occupational distribution of this area[6], we have divided the conscripts into five occupational categories: a) the first group consists of agricultural day-labourers and unskilled factory employees; b) the second group is composed of farmers (landowners). Conscripts only appear in this category if they were always registered as 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 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, covering a range of occupations, such as shepherds, military personnel, muleteers, drivers of diverse vehicles, etc. In our case, only 38.6 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 the size of the family of origin. This takes into account whether the parents were still alive at the time of conscription and the number of siblings who lived with the individual for at least five years. This variable can be of interest given that a large family size could be linked to greater competition for family resources, affecting the biological welfare 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.

Spanish military conscripts provide other data of interest. Particularly noteworthy are the data on the state of health and the socioeconomic circumstances of the conscripts at the time of measurement. Thus, we have included in our analysis the information of appeals for exemption on physical and socioeconomic 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. Both indicators provide information on health and family conditions, such as the state of poverty or orphanhood.

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, 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, 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 (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

[6] 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.

(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).

Likewise, we have also introduced into our analysis the number of economic crises experienced by the conscripts during their adulthood. These crises could have had effects on food consumption, affecting the life span of individuals. 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 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[7]. 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, 1953, 1959, 2009, 2011 and 2012.[8]

Finally, we have also included in the analysis as a control variable the causes of 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.

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 and epidemiological 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).[9] For the statistical analysis of our data we have used ordinary least squares (OLS) linear regressions with heteroskedasticity-robust estimation.

4. Results and Analysis

First, we have analysed some of the determinants of biological welfare 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 welfare at the age of 21 was conditioned by socio-economic, educational, health and family conditions. The statistical analysis confirms, in the same way as other studies, that there is a relationship between the occupational category of the father and the biological welfare 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

[7] Personal communication of Prof. Vicente Pinilla (Universidad de Zaragoza, vpinilla@unizar.es).

[8] For more information on this issue, see Marco-Gracia (2017).

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

socioeconomic level (day-labourers and low skill employees) were those with the lowest levels of biological welfare. They were, on average, 0.2 cm shorter than the artisans' sons, 1.0 cm smaller than the farmers' sons, and 1.9 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 welfare of children.

The literacy of the conscripts also proves to be strongly related to their biological wellbeing, 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 wellbeing according to our results, thus confirming the importance of health status on physical growth. Finally, we have included a variable referring to the family size of origin in the model. The results show that conscripts coming from small families had lower levels of biological welfare. The result does not corroborate the resource dilution hypothesis, as documented for a nearby area (Ramon-Muñoz and Ramon-Muñoz, 2017). On the one hand, low family size could be the consequence of the early death of one of the spouses, which has been shown to negatively affect biological welfare (Reher and González-Quiñones, 2003). On the other hand, given that the fertility transition was in its early stages (Marco-Gracia, 2018b), the small family size may have been linked to families of low income that had experienced higher childhood mortality.

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	-9.18**	-9.97**	-9.03**	-9.84**	-8.03**	-9.22**
		(4.08)	(4.08)	(4.07)	(4.06)	(4.06)	(4.07)
	Artisan	-4.44	1.78	-4.19	1.82	-1.99	3.23
		(7.77)	(7.61)	(7.72)	(7.56)	(7.71)	(7.57)
	Upper class	8.13	1.18	10.22	2.94	13.89	5.43
		(16.67)	(16.27)	(16.56)	(16.16)	(16.53)	(16.18)
	Other or unknown	-7.36*	-13.20***	-7.03*	-13.34***	-6.73	-13.01***
		(4.25)	(4.56)	(4.24)	(4.54)	(4.23)	(4.55)
Literacy	Illiterate	(ref.)					
	Literate	16.45***	10.39*	14.62**	8.82	15.01**	9.24
		(5.93)	(5.91)	(5.92)	(5.91)	(5.91)	(5.90)
	Unknown	-15.56**	1.09	-16.71**	0.73	-17.37**	0.59
		(6.93)	(8.07)	(6.92)	(8.05)	(6.92)	(8.05)
Appeals for exemption	No appeal (fit to serve)	(ref.)					
	Physical appeals			-29.79***	-28.50***	-29.20***	-28.01***
				(6.28)	(6.17)	(6.25)	(6.17)
	Social appeals			2.48	4.58	3.61	5.29
				(4.89)	(4.79)	(4.89)	(4.79)
Family size (including parents)	0-4 people					-9.47***	-6.61*
						(3.53)	(3.51)
	5-6 people	(ref.)					
	7 or more people					7.63	4.80

					(5.67)	(5.64)
Intercept	1635.5***	1610.1***	1638.8***	1614.0***	1641.6***	1614.1***
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	0.06	0.12

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.

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 seven regressions carried out to estimate these determinants. 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. In models 1, 2, 3 and 4 we introduced the variable of height as a continuous variable. In regression 1 we analysed exclusively this variable. In models 2 and 3, it was combined with other socioeconomic, family and control variables. In all of them, we can observe the existence of a strong correlation between height and life span. In models 5 and 6, we introduced height categorised by percentiles for the whole period. The results have a high level of significance and show that medium-tall and tall conscripts had longer life spans, being slightly longer in the case of the former. The life span of both groups was, on average, up to 3.4 years longer than that of the medium-short individuals. Finally, in the model 7 we introduced height distributed by percentiles for each subperiod (for more information on distribution, see the note accompanying Table 5). Again, the results confirm that medium-tall and tall individuals had a longer average life span. Therefore, 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.

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)**	**(7)**
Height	Continuous variable	0.024***	0.025***	0.014**	0.016***			
		(0.01)	(0.01)	(0.01)	(0.01)			
Height categorised by percentiles	Short (P0-P25)					-0.610	0.628	
	<=160 cm					(1.31)	(0.93)	
	Medium-short (P26-P50) >160-<=164 cm				(ref.)			
	Medium-tall (P51-P75)					4.337***	2.535***	
	>164-<=168 cm					(1.33)	(0.94)	
	Tall (P76-P100)					2.331*	2.297**	
	>168 cm					(1.34)	(0.95)	
	Short (P0-P25)							-0.202

							(0.94)	
Height categorised by percentiles according to period (++)	Medium-short (P26-P50)			(ref.)				
	Medium-tall (P51-P75)						1.920**	
							(0.94)	
	Tall (P76-P100)						2.064**	
							(0.93)	
Occupation	Farmer			(ref.)				
	Low skilled worker	-3.878***	-3.265***	-1.040		-1.102	-0.771	
		(1.28)	(1.24)	(0.98)		(0.98)	(1.00)	
	Artisan	-5.846**	-3.199	-1.039		-1.077	-1.440	
		(2.54)	(2.36)	(1.87)		(1.87)	(1.91)	
	Upper class	-5.065	-1.322	0.840		0.957	1.670	
		(4.45)	(4.09)	(3.24)		(3.25)	(3.31)	
	Other	6.590***	7.816***	3.992***		4.002***	3.864***	
		(1.30)	(1.22)	(0.98)		(0.98)	(1.00)	
Number of economic crises experienced from the age of 21	Zero				(ref.)			
	One				9.831***		9.792***	10.310***
					(2.19)		(2.19)	(2.23)
	Two				17.383***		17.274***	18.288***
					(2.16)		(2.16)	(2.21)
	Three				19.813***		19.704***	20.844***
					(2.15)		(2.15)	(2.19)
	Four				25.842***		25.728***	27.058***
					(2.04)		(2.04)	(2.07)
	Five				30.493***		30.421***	30.133***
					(2.16)		(2.16)	(2.21)
	Six or more				34.933***		34.875***	35.919***
					(1.92)		(1.92)	(1.96)
Dying in war or post-war years	No				(ref.)			
	Spanish Civil War (1936-1939)				-20.472***		-20.085***	-21.660***
					(2.95)		(2.96)	(3.01)
	1st decade of post-war (1940-1949)				-12.694***		-12.727***	-13.808***
					(1.51)		(1.51)	(1.52)
	2nd decade of post-war (1950-1958)				-15.136***		-15.258***	-15.524***
					(1.46)		(1.46)	(1.47)
Dying in an epidemic year	No				(ref.)			
	Yes				-3.304		-3.186	-8.113***
					(3.06)		(3.06)	(3.06)
Relatives alive at death in the same locality	0 to 2 people			2.047*		1.832	1.765	
				(1.13)		(1.13)	(1.15)	
	3 to 5 people			(ref.)				
	6 or more people			-2.507*		-2.605*	-2.574*	
				(1.44)		(1.44)	(1.47)	

Intercept	28.77**	25.71**	28.57***	5.22	66.78***	29.99***	37.59***
Control Cause of death	NO	NO	SÍ	SÍ	NO	SÍ	SÍ
Control village	NO	NO	SÍ	SÍ	NO	SÍ	SÍ
Control birth decade	NO	NO	SÍ	SÍ	NO	SÍ	NO
N	1,488	1,488	1,488	1,488	1,488	1,488	1,488
R-sq	0.008	0.080	0.246	0.535	0.012	0.536	0.516

Notes: OLS estimates; *se* denotes robust standard error. (++) For the subperiod 1835-1869 the quartiles remain: Q1. <=1565; Q2. >1565 - <=1610; Q3. >1610 - <=1645; Q4. >1645. For the subperiod 1870-1899 the quartiles remain: Q1. <=1595; Q2. >1595 - <=1625; Q3. >1625 - <=1670; Q4. >1670. For the subperiod 1900-1930 the quartiles remain: Q1. <=1609; Q2. >1609 - <=1650; Q3. >1650 - <=1686; Q4. >1686. 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 2 and 3 find a relationship between occupation and life span, also found in southern Spain in the nineteenth century (Luque, 2020). However, this relationship is no longer significant in the more complete models. Meanwhile, the number of economic crises experienced during adulthood appears to be a factor favouring long life spans. The result suggests that individuals living longer lives are more likely to have experienced more years of bad economic situations. Thus, the average age of death of those who lived through two crises was 10.6 years less than those who lived through four, and 14.4 years less than those who lived through six or more economic crisis years (Tabla 5, models 4, 6 and 7).

Likewise, our results reveal that 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 individuals in the sample. The variable 'dying in a pandemic year' is also significant but only in model 7. In this case, those who died in a pandemic year had a shorter life span.

Finally, in models 4, 6 and 7 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 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 (Lana Berasaín, 2002, 2007). 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).

Figure 3 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. 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. In this case, the short individuals had the same or even longer life span as the tall subjects because they had greater potential for growth when their health and nutritional conditions improved. These 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).

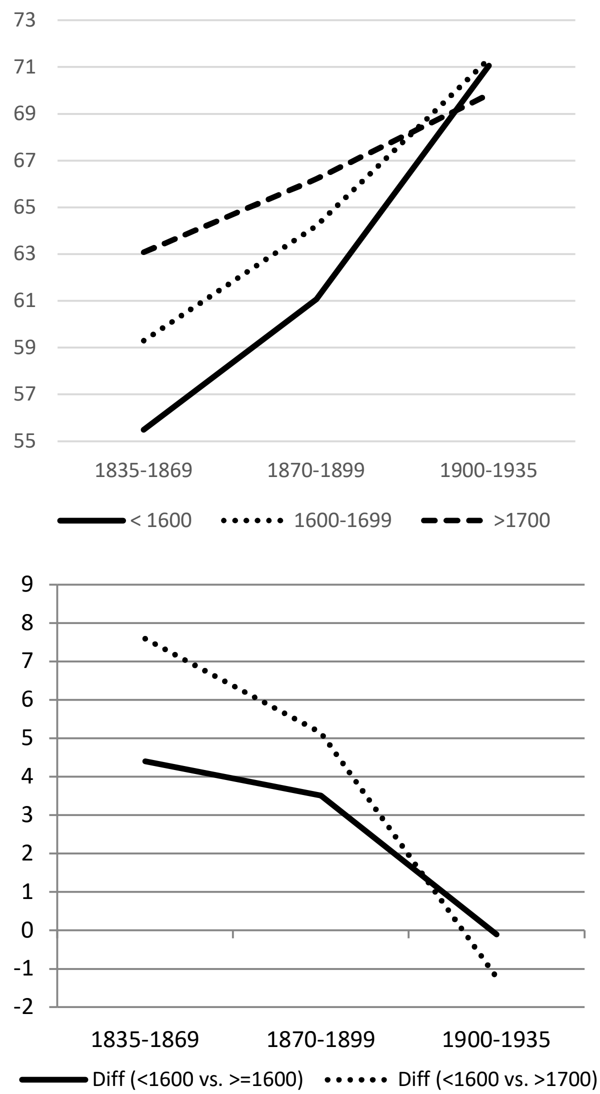

Figure 3. Average life span according to height group and birth date, and average gap in life span depending on height group, birth cohorts 1835-1939. Source: Parish registers, censuses and conscription and call-up records; historical municipal and parish archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

In Figure 4, we have calculated life expectancy according to height group and decade of birth for the period 1890-2019. However, in this case we have only taken into account men over 21 years of age and calculated it 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. 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, 2002; 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 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, life expectancy exceeded 80 years for all groups.

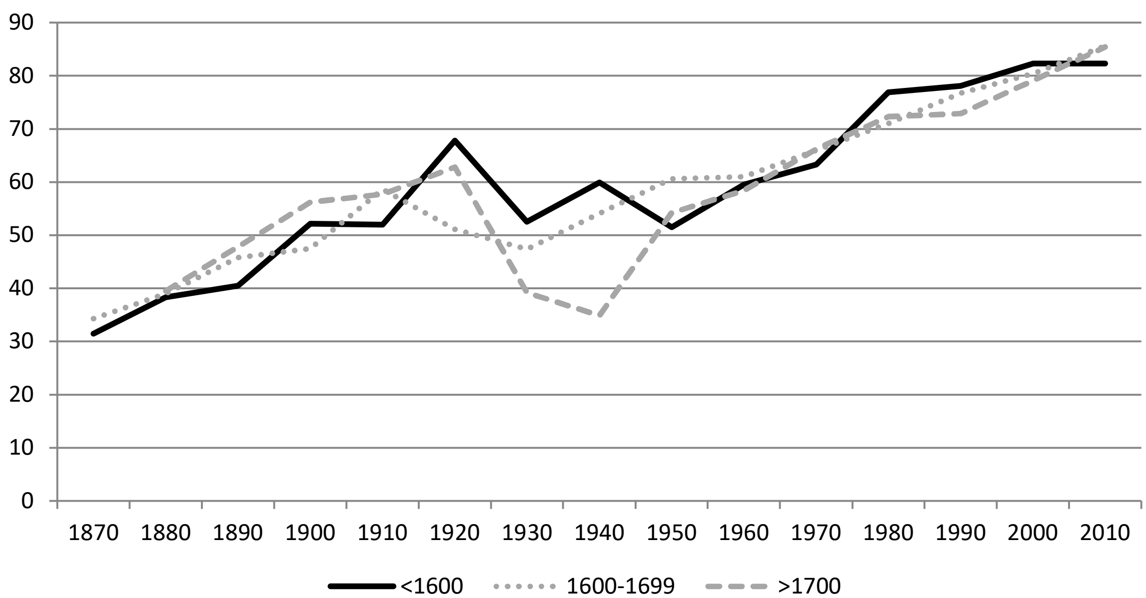

Figure 4. Evolution of life expectancy according to height group and decade of birth, 1890-2019. Scheme 1980. s, Waaler (1984) established the existence of a relationship between height and life span in Norwegian adults during the twentieth century. Subsequently, this relationship has been the subject of new studies (Fogel, 1994; Baten and Komlos, 1998; Smith et al., 2000; Costa, 2004; Alter et al., 2004a; Thompson et al., 2020). However, we know little about it and its evolution over the very long term. This paper contributes to this issue by analysing several family and socio-economic variables to discover whether height can be a good indicator of life span.

In our study, we have analysed the case of 1,488 conscripts from rural Spain born between 1835 and 1939. From these data we have performed analyses with ordinary least-squares regressions (OLS). The first analysis enabled us to establish some of the determinants of biological welfare. The results obtained show that 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 welfare.

In the second analysis we studied some of the determinants of life span in adulthood, explaining 50% of these determinants. In this analysis, height is shown to be a decisive factor for the whole study period. The main differences by age group are between short and medium-short men (until 164 cm) and medium-tall (165-168 cm) and tall individuals (168 cm or more), with no important differences between short and medium-short, and medium-tall and tall. 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 of 1936-1939 and the long post-war period had a negative effect on the average life span, explained above all by nutrition problems and poor hygienic-sanitary conditions. At the family level, the presence of many living relatives competing for family resources also had a negative impact.

Genetic factors could have influenced our results. It has been shown that approximately 80% of height is conditioned by genes (Silventoinen, 2003; McEvoy and Visscher, 2009; Grasgruber et al., 2014). A relationship between genetics and longevity has also been demonstrated (Gjonça and Zaniotto, 2008; Van den Berg et al., 2019). However, it has not been possible to establish that genes linked to a taller stature are linked to greater longevity. Therefore, other factors, mainly nutritional, socioeconomic and environmental, could be the cause of the strong positive correlation between height and life span over the long term.

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, 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 we have found similar life spans for all height groups. During this period there were significant improvements in living conditions and diet in Spain which contributed to closing the anthropometric gap and increasing the average 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).

To conclude, we believe that the results obtained in this study may be important in ways that go beyond providing historical knowledge. For example, the pernicious relationship between low biological wellbeing and a short life span 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. This study has allowed us to offer novelties with conclusions that must be confirmed with studies for other samples and areas.

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

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Appendix

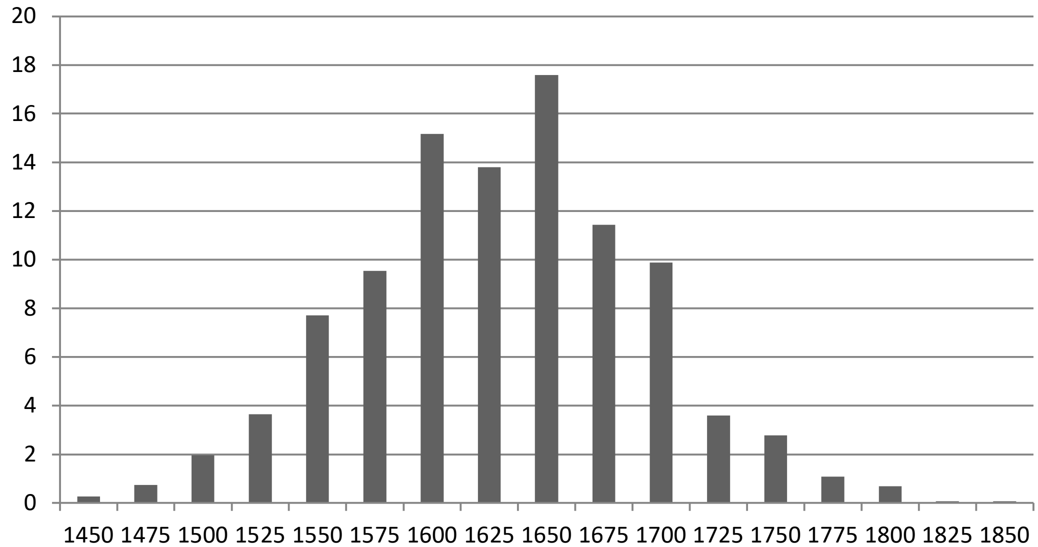

Figure A1. Distribution of heights in the complete period, birth cohorts 1835-1939. Sample: 1,488 heights. Mean=164.0, Std. Dev. =1.7. Source: Conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample and conscription records of the Military Archive of Guadalajara (Spain).

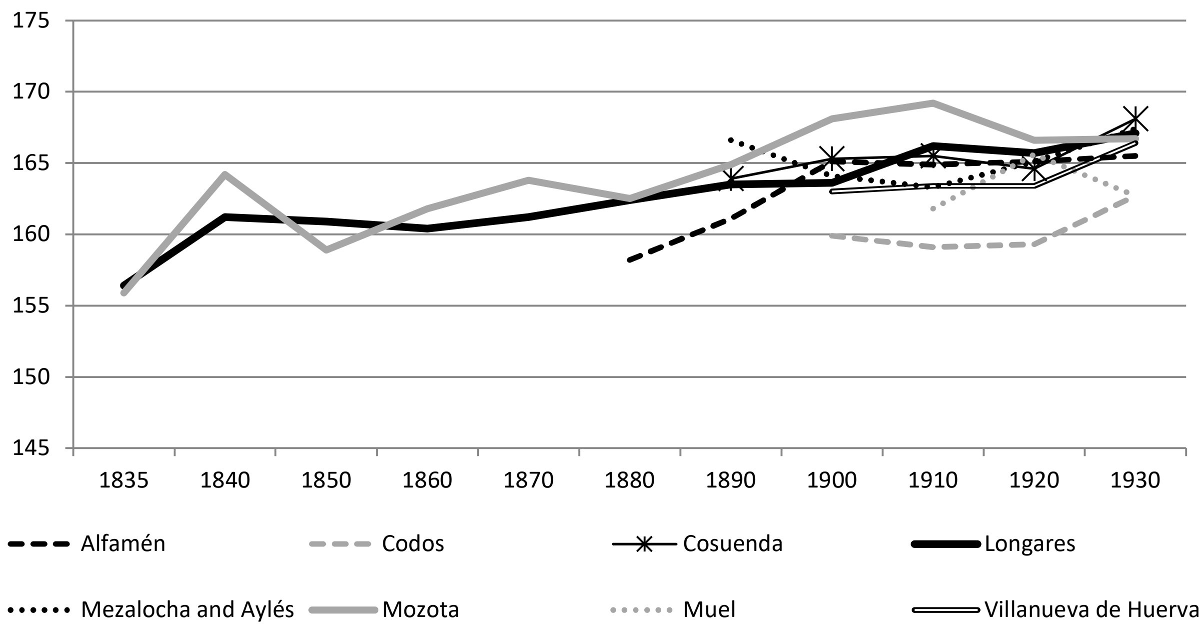

Figure A2. Comparison of average height according to municipality and decade of birth (period in which data are available in municipal archives). Note: We have included only municipalities with a height sample over 80 observations. The thickest lines correspond to Longares and Mozota, the municipalities 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	64	34.59	159.7	7.4	48.6	1.8
	Farmer	33	17.84	161.1	12.3	54.2	3.0
	Artisan	11	5.95	164.5	16.7	51.2	5.9
	Upper class	1	0.54	168.6		49.0	0
	Other or unknown	76	41.08	161.4	7.1	68.8	1.5
Father's occupation	Low skilled worker	49	26.49	160.4	8.2	56.2	2.5
	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	49	26.49	160.4	8.5	57.6	2.4
Family size (including parents)	0-4 people	66	35.68	160.6	7.7	58.5	2.3
	5-6 people	110	59.46	161.1	6.0	58.8	1.6
	7 or more people	9	4.86	162.2	26.0	45.7	5.4
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
Appeals for exemption	No appeal (fit to serve)	150	81.08	161.3	5.1	58.2	1.4
	Physical appeals	16	8.65	157.3	17.6	52.7	4.5
	Social appeals	19	10.27	161.6	12.3	61.9	4.0
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
Number of economic crises experienced (after age 21)	Zero	12	6.49	158.6	15.1	42.0	6.1
	One	20	10.81	159.5	12.7	32.5	1.3
	Two	18	9.73	160.6	15.2	43.5	1.3
	Three	13	7.03	162.8	16.7	40.7	2.3

	Four	20	10.81	160.5	13.3	51.4	1.4
	Five	39	21.08	161.8	11.6	63.4	0.9
	Six or more	63	34.05	161.2	8.0	75.8	0.9

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	85	37.95	161.9	6.4	54.1	1.9
	Farmer	27	12.05	162.9	10.6	59.3	3.5
	Artisan	9	4.02	165.1	8.6	62.5	8.0
	Upper class	2	0.89	169.5	10	75.7	11.1
	Other	101	45.09	163.8	5.2	72.7	1.1
Father's occupation	Low skilled worker	99	44.20	162.6	5.8	61.4	1.8
	Farmer	63	28.13	163.4	7.1	65.2	2.1
	Artisan	13	5.80	166.0	12.6	67.4	5.5
	Upper class	1	0.45	162.0	-	50.7	-
	Other or unknown	48	21.43	162.8	7.3	65.8	2.9
Family size (including parents)	0-4 people	109	48.66	162.9	5.2	65.0	1.6
	5-6 people	100	44.64	163.2	5.8	63.8	1.8
	7 or more people	15	6.70	163.6	11.9	53.5	5.6
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

Appeals for exemption	No appeal (fit to serve)	180	80.36	162.7	3.9	62.7	1.4
	Physical appeals	11	4.91	164.3	25.0	66.9	5.0
	Social appeals	33	14.73	164.5	10.6	67.8	2.3
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
Number of economic crises experienced (after age 21)	Zero	12	5.36	164.6	11.3	25.8	0.8
	One	7	3.13	158.0	14.4	30.0	2.1
	Two	7	3.13	160.0	7.7	33.6	2.4
	Three	8	3.57	163.5	20.5	47.7	1.5
	Four	7	3.13	162.0	40.7	44.9	2.5
	Five	16	7.14	165.2	13.0	52.4	1.1
	Six or more	167	74.55	163.1	4.2	71.7	0.9

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	450	41.71	164.7	3.1	67.7	0.8
	Farmer	201	18.63	165.3	4.6	71.1	1.2

	Artisan	36	3.34	164.9	11.2	65.2	3.1
	Upper class	13	1.20	166.5	17.7	62.6	7.3
	Other	379	35.12	164.2	3.3	75.6	0.6
Father’s occupation	Low skilled worker	332	30.77	164.3	3.6	70.2	1.0
	Farmer	366	33.92	165.4	3.4	72.4	0.8
	Artisan	47	4.36	163.6	10.6	70.8	2.2
	Upper class	13	1.20	166.0	12.1	66.0	4.9
	Other or unknown	321	29.75	164.3	3.5	70.3	1.0
Family size (including parents)	0-4 people	540	50.05	164.0	2.8	73.1	0.6
	5-6 people	405	37.53	165.1	3.2	69.3	0.9
	7 or more people	134	12.42	165.9	5.9	67.4	1.8
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
Appeals for exemption	No appeal (fit to serve)	846	78.41	165.0	2.1	71.6	0.6
	Physical appeals	85	7.88	161.2	9.5	65.1	2.3
	Social appeals	148	13.72	164.7	5.3	70.9	1.3
Dying in an epidemic year	Yes	0	0.00				
	No	1,079	100.00	164.7	2.0	71.0	0.5
Dying during the war and post-war	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
	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
Number of economic crises experienced (after age 21)	Zero	23	2.13	167.3	12.7	35.0	3.3
	One	86	7.97	165.6	8.0	55.5	2.0
	Two	98	9.08	165.5	6.3	65.0	1.6
	Three	110	10.19	164.6	6.2	65.4	1.6
	Four	213	19.74	164.7	4.5	73.3	0.9
	Five	72	6.67	164.4	7.2	81.5	1.7
	Six or more	477	44.21	164.2	2.9	75.4	0.7

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 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.

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