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Did parental care in early life affect height? Evidence from rural Spain (19th-20th centuries)

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ABSTRACT

This article examines the relationship between childhood mortality experienced within families and the height of surviving male children. Sibling mortality, controlled by different socioeconomic and environmental variables, is used as an approximation of the hygienic and epidemiological context and practices within the family. The analysis is based on a sample of 2783 individuals born between 1835 and 1977 in 14 villages in north-eastern Spain. The mortality data were obtained from the parish archives of the reference villages, and the height data from military service records of conscriptions at 21 years of age. The data were linked according to nominative criteria using family reconstitution methods. The results suggest the existence of a strong negative relationship between height and the childhood mortality experienced within families. Children born in families in which 50% of the children died before the age of five were up to 2.3 cm shorter than those of families with childhood mortality of less than 25%. General socioeconomic, hygienic and health improvements reduced childhood mortality, causing this link to gradually disappear between the 1940s and 1970s.

1. Introduction

In recent decades, a growing amount of literature has demonstrated that height can be considered a good indicator of the biological well-being of human populations (Komlos and Baten, 2004; Steckel, 2008, 2019; Komlos, 2009; Craig, 2014; Komlos and Kelly, 2016). Some factors, such as the socio-economic status of the parents and the educational level, have also been found to be closely related to the biological well-being (Tanner, 1978; Silventoinen, 2003; Akachi and Canning, 2007; López-Alonso, 2007; Steckel, 2009; Hatton, 2014; Ayuda and Puche-Gil, 2014; Bogin, 2020). The analyses illustrate that the factors linked to development during childhood and adolescence play a fundamental role in the quality of life. This research seeks to determine whether there has been a historical relationship between parental care and the biological well-being of individuals. For the purpose of this article, we understand parental care to mean a wide range of practices in the household context related to hygienic conditions, food preservation, exposure of children to animals and pathogens, general care and parental attitudes towards risk and their children.

Infant mortality is considered to be a good approximation of the living standards of a society, as it is strongly related to the economic situation and the development of widespread health programmes (Waldmann, 1992; Alves and Belluzzo, 2004). At the same time, living conditions during childhood have been shown to be correlated with height during adulthood (Crimmins and Finch, 2006; Webb et al., 2008), with the infancy period being especially important (Schmidt et al., 1995; Stein et al., 2010). For this reason, in recent decades many studies have analysed the relationship between infant mortality rates and changes in height. The most popular way of approaching this relationship has been through post-neonatal mortality rates (PNM): the mortality of children who lived past the first month of life and died before the first year (usually from digestive and respiratory diseases). The results tend to confirm the existence of a negative relationship between PNM rates and the average height of that generation (Schmidt et al., 1995; Martínez Carrión and Pérez Castejón, 2002; Bozzoli et al., 2009; Hatton, 2011, 2014, 2014; Spijker et al., 2012). In Spain, a reduction in the infant mortality rate of 30 individuals per 1000 between 1961 and 1980 was associated with an increase of 2.7 cm (Quintana-Domeque et al., 2011). However, a weak, non-lineal correlation has been found for Sweden (Öberg, 2015) and for many developing countries (Deaton, 2007; Akachi and Canning, 2010; De Oliveira and Quintana-Domeque, 2014). In any case, these studies focus on the effect of *overall* mortality on average

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heights. Our study, however, seeks to analyse the effect of mortality experienced *within* the family at the *individual* level.

Variability in height is influenced by environmental factors (Silventoinen, 2003; McEvoy and Visscher, 2009; Hatton, 2014). These include nutritional, socio-economic, and epidemiological aspects (Hatton, 2011). For instance, the exposure of children to certain microbes, such as *H. pylori* (Beard and Blaser, 2002), and their suffering from certain diseases such as pneumonia (Bozzoli et al., 2009) or smallpox (Voth and Leunig, 1996) have been associated to shorter adult height.[1] However, what most affects height is the accumulation of diseases (Stephensen, 1999; Oxley, 2003; Moradi, 2010; Floud et al., 2011; Hatton, 2011; Sharpe, 2012). The human body is able to recover from an occasional and temporary illness, but body growth can be affected if the illness is prolonged over time and the person falls ill repeatedly (Tanner, 1978; Thompson et al., 2020). Therefore, to experience lower height in adulthood, and for the human body not to catch up, more continuous exposure to pathogens or diseases might be necessary, which would be linked to less hygienic and healthy environments. In most of these cases, the protective and hygienic role undertaken by the parents is of utmost importance to reduce the possibility of children suffering multiple and continuous diseases.

In this paper, we will attempt to examine the role of parents in caring for their children by considering the sibling mortality experienced in the family home. We also seek to assess how this family context affected the biological well-being (as measured by heights) of surviving children. Our aim is to study the impact of variables specific to the family environment, attempting to isolate them from a context in which multiple factors of a biological, ecological and cultural nature interacted with each other at different critical stages of growth and had an impact on the height reached by individuals (on the critical stages of physical growth see Bogin et al., 2018).

Many of the factors linked to mortality (such as exposure to certain diseases) could not be avoided by families. Sibling mortality was indeed conditioned by genetic factors and overall mortality, but also by family living conditions. These were affected by factors such as family income (which we will control through the parental occupation), but also by a wide range of practices in the household context and by the hygienic conditions in the child's environment. Households had an important role in the management of the hygienic environment in the study area since they influenced highly important factors such as food preservation (refrigerators did not become popular due to their price until the 1960s–1970s) or personal hygiene (in some of the localities running water did not reach households until the 1970s–1980s). Death is an extreme indicator of illness, yet we do not have information on how many illnesses and how severely each person was affected. We do know, however, how many siblings died and what percentage they represented of the total offspring. Were individuals from families with the highest mortality those with the shortest average height?

In this article, we have used the data of 2783 conscriptions of men born between 1835 and 1977 in 14 Spanish villages. We have applied the family reconstitution method (Fleury and Henry, 1956) using the parish records of baptism, marriage and death, and linked life trajectories with height and socio-economic data. Therefore, we have information on their life trajectories and those of their families. In Spain, a universal system of conscription had been in place since the 1830s; therefore, all men had to be measured at approximately 21 years of age (exceptions were made only for fugitives and occasionally for emigrants). Individuals who were short or had health problems were also required to register and undergo a medical examination. This allows us to avoid some biases existing in the data of other countries. This is not to say that there were no legal mechanisms for evading compulsory military service. In fact, from 1837 to 1936, there were alternatives such as paying large sums of money to evade it. But all these options were put into practice after conscription (Puell de la Villa, 1996; Verdejo Lucas, 2004; Puche-Gil, 2009, 2011).

This research is innovative for a number of reasons. First, this article analyses the relationship between heights and the household context in the very long-term. Second, it takes an innovative perspective using data on infant mortality within the family for complete families. Third, it provides new evidence regarding the influence of a wide range of environmental and socioeconomic variables on biological well-being. Finally, this study may have practical applications, since it demonstrates the importance of maintaining clean environments for the complete development of children.

2. Data & methods

Our database contains information on 14 Spanish rural villages in the region of Aragon (see Fig. 1). These villages are: Alfamén, Aylés, Botorrita, Codos, Cosuenda, Jaulín, Longares, Mezalocha, Mozota, Muel, Torrecilla de Valmadrid, Tosos, Valmadrid and Villanueva de Huerva. The villages are located around the middle section of the Huerva River, in the lower mountains of the *Sistema Ibérico* and, mostly on the plains. Aragon underwent a transformation and modernisation process from the mid-nineteenth century onwards (Germán, 1993, 2012) that concentrated in the regional capital (Zaragoza) but was less intense in the small villages of the area (Germán, 2000). The modernisation process favoured migrations from the villages to the capital (Silvestre, 2005). In 1857, Aragon was not an important industrial area in comparison to other Spanish regions, ranking ninth out of 14 in terms of industrialisation (Calatayud, 2001; Carreras, 2005). While the first stages of economic modernisation, linked to the development of the industrial sector, coincided with the first wave of globalisation (Pinilla and Ayuda, 2009; Germán, 2012), the process was interrupted by the Spanish Civil War (1936–1939). Aragon did not recover from this shock until a quarter of a century later (Germán, 2012).

The majority of the population in the area of study (approximately 80% of the registered workers during the first half of the twentieth century) were engaged in agricultural work, mainly in the production of cereals, sugar beet, wine and sheep meat and as in the region as a whole, their main market was the Spanish domestic market (Germán, 2012). The case of wine is particularly interesting, given that the French phylloxera crisis at the end of the nineteenth century led to an increase of wine production (Pinilla Navarro, 1995).

The area of study covers around 500 kms[2] and had a population of 7926 inhabitants in 1860, 8196 in 1900, 10,672 in 1940 and 6829 in 1981 (for more details see Table 1). The majority of the population in the rural study area was engaged in subsistence farming, so most of them had living standards close to subsistence (Marco-Gracia, 2018). These low levels were aggravated by the low productivity of the land, which was mostly arid, with the exception of the banks of the river Huerva, where fruit and vegetables could be grown. The study area was also characterised by the predominance of nuclear family households.

The fertility transition only began in Aragon at the beginning of the twentieth century. Up to that time, parish records confirm that the average marital fertility in the area of study for complete families was between 6 and 7 children (typical of a pre-transitional society). With the onset of the fertility transition, the average number of offspring declined rapidly (Marco-Gracia, 2021). Pre-transitional child mortality was also very high, with approximately 50% of children dying before the age of seven. However, with the first stages of the demographic transition, in the last third of the nineteenth century, mortality also began to decline (Marco-Gracia, 2017). In relation to our study, conscripts had an average height of approximately 160 cm during the twentieth century,

[1] Oxley (2003) found no such relationship between smallpox and height.

[2] Figure A2 in the supplementary online material shows the distribution of heights by decade of birth, and Figure A3 shows the distribution of heights according to the total number of siblings.

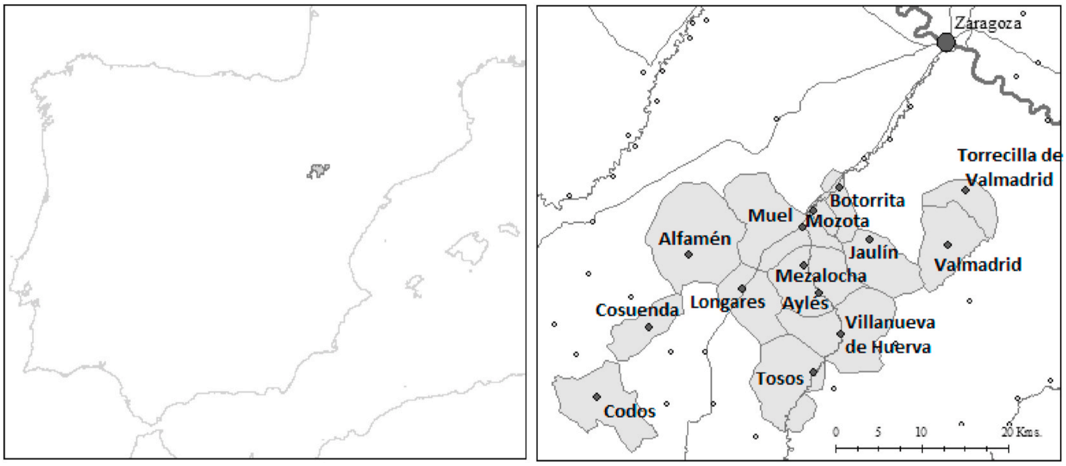

Fig. 1. Area of study: Middle Huerva (Aragón, Spain).
Source: Own elaboration.

Table 1
Changes in population size over time, 1860–1981.

	Population			
	1860	1900	1940	1981
Alfamén	604	639	1347	1283
Aylés	45	26	47	0
Botorrita	294	350	557	382
Codos	1232	1195	938	355
Cosuenda	1451	1270	929	482
Jaulín	390	348	528	334
Longares	1120	1329	1385	959
Mezalocha	544	482	660	357
Mozota	292	372	404	158
Muel	1223	1206	1605	1330
Torrecilla de Valmadrid	164	77	94	32
Tosos	682	865	801	297
Valmadrid	203	210	219	89
Villanueva de Huerva	690	970	1158	771
TOTAL	7926	8196	10,672	5632

Source: Spanish Statistical Institute (www.ine.es/intercensal/).

which was shorter than conscripts in other Spanish regions (Quintana-Domeque et al., 2012; Martínez-Carrión et al., 2016).

Fig. 2 illustrates the evolution of height and childhood mortality (under 5 years) in the area of study. Height increased strongly during the twentieth century, whereas childhood mortality began to decline in the final decades of the nineteenth century. These processes co-existed with a gradual improvement in living standards over the whole period (Martínez-Carrión and Puche-Gil, 2009).

In this article, we use three kinds of data: height, demographic and socioeconomic data. The height data were collected from the municipal archives of each of the reference villages. In total, we have been able to follow the course of life of 2783 individuals. Due to the fact that in certain exceptional years the age of conscription was modified, we have standardised the data to 21 years, obtaining results similar to those found for other Spanish conscripts (Ramón Muñoz, 2011; Ayuda and Puche-Gil, 2014). With our data, we can confirm that the distribution of heights is close to normal[2] (see Fig. A1 in the supplementary online material) and cannot reject the null hypothesis of normality of average height for a significant level of 5%.

Demographic data on baptism, marriage and death have been collected from the parish archives. The parish registers provide us with high quality individual-level data of all events occurring between the sixteenth century and 1950, although the starting date varies by location (in all cases, the demographic data started before the height data so no conscript was left out of the analysis).[3] For the period after 1950, a total of 1074 personal interviews with relatives of the analysed individuals were conducted to obtain similar data.[4] The database was developed using the family reconstitution method formulated by Fleury and Henry (1956) and includes information on all individuals born in the villages of the area of study and those who migrated to the villages and were registered upon the occurrence of an event (such as marriage, birth of a child or death). This dataset contains information on approximately 125,000 individuals.

The occupation of the analysed individuals and their fathers and data on literacy 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] Information on occupations, literacy and heights was linked to the population records for each individual. Table 2 shows the distribution of all available variables in our sample, as well as the distribution of height across those variables. The large differences in heights found by village are mostly related to the different starting years of the data available for each village (see Figure A4 in the Appendix for a comparison by decades). In Table 2 we have added in parenthesis the starting year of the data available for each village.

Locality of residence is a control variable that allows us to test whether there were significant differences in the environmental and socioeconomic conditions across villages. *Birth decade* is a key indicator both of the socioeconomic and political context and of the process of social and demographic modernisation.

Among the socioeconomic variables, *literacy* allows us to study the effect that access to education had on biological well-being, especially as an approximation of the investment that parents made in their children. We consider a person to be literate (or illiterate) if the census and population registers show him or her as such during adulthood (the census includes a question as to whether the person is literate). During the period of study, Spain experienced a rapid increase in literacy rates, from 27% in the 1860 population census to three quarters in the 1930 population census (Núñez, 2005). On the other hand, *Father's occupation*

[3] For more details about the 'Alfamén and Middle Huerva Database' (Marco-Gracia, 2017, 2019).

[4] We requested information regarding dates of demographic events, occupation, and education.

[5] Data that appear randomly depending on the parish priest.

Fig. 2. Changes in body height against a decline in child (under-five) mortality rates, 1835–1977.
Source: Parish registers of death and conscription and call-up records; historical municipal archives from municipalities composing the anthropometric sample.

serves as an approximation of the living standards in the family household since it provides an insight into family income. As most observations of occupations are concentrated in two agricultural categories (day labourers and farmers) we have chosen to use our own classification of occupations adapted to the study area rather than an international classification. We have established five categories: (1) agricultural day-labourers and unskilled factory employees; (2) farmers; (3) landless or semi-landless artisans: potters, bakers, blacksmiths, tailors, etc.; (4) skilled workers in services such as doctors, teachers, veterinarians, or station masters, and (5) 'others', includes the rest of the occupations that could not be classified in the previous categories (such as shepherds, military personnel or muleteers).[6]

From the conscription records, we have also obtained information on the health status of conscripts at the time of measurement. They could claim health reasons for evading compulsory military service, as well as social problems (such as poverty or orphanhood). We have included a variable, *appeals for exemption*, which contains these allegations if they were accepted by the court as legitimate. Our dataset also includes a variable on the *number of living siblings (surviving over 5 years)*, which may be of great interest given that large families could have experienced a greater competition for resources (Öberg, 2017). In order to test whether the birth position had any effects on the biological well-being of the children, we have also incorporated *parity*.

The *number of pandemic crises* variable accounts for the number of years during the infancy/adolescence of the individual (until 21 years old) that were pandemic years. There were two important pandemic diseases during the period studied: (1) the Cholera outbreaks of 1855 and 1885, and (2) the 1918–1920 flu pandemic, which in Spain alone resulted in 260,000 deaths (Echeverri, 1993; Nicolau, 2005). In addition to the epidemiological crises, we have included a variable of the *number of economic crises* experienced by the conscripts during infancy and adolescence, since these may have affected the quantity and quality of their food consumption. Drawing on Peiró's (1987) data, we have identified the years in which wheat prices in the city of Zaragoza rose by more than 10%. We controlled for the trend using a Hodrick-Presscott filter (Hodrick and Prescott, 1997) and found the following crisis years: 1836, 1837, 1841, 1846, 1855, 1856, 1867, 1881, 1891, 1896 and 1897. Given that in the twentieth century the integration of markets led to a significant decrease in the number and intensity of wheat crises, from 1900 onwards we have used GDP per capita data for the province of Zaragoza instead.[7] Drawing on this series, we have considered as years of economic crisis those years in which the GDP per capita contracted below the levels of the previous year. These years were: 1910, 1926, 1928, 1931, 1933, 1936, 1937, 1938, 1945, 1949, 1953 and 1959, 2009.

Finally, we have included information on the *percentage of deceased siblings*. As we shall discuss, this will allow us to control for the general epidemiological and mortality context but also for the specific practices within the household. We have only considered complete families (i.e. families in which both parents lived to the age of 49 and for which we know the dates of the events of all their children) and calculated the percentage of siblings of the individual who died before the age of one and five. The reason for using percentages rather than total numbers is that they allow us to approximate the situation of the household of residence more adequately. In decades of high marital fertility (all except for the most recent), percentages allow us to differentiate between households with high mortality and 'healthy' households. That is, the percentage better informs us about family success in raising children than the specific number of deaths.

In Table 2, the *percentage of deceased siblings* refers to the fraction of siblings who died before their fifth birthday. This indicator may be understood as a proxy for parental care and the hygienic-epidemiological context in which the individuals grew up. This variable has been introduced into the subsequent analysis in two different ways: (a) as a continuous variable and (b) as a categorical variable divided into three categories: (1) between 0% and 24.9% of deceased siblings; (2) between 25% and 49.9% and (3) 50% or more of deceased siblings. These categories will help us to analyse whether a high percentage of mortality in a household is related to low levels of biological well-being (despite a lower level of competition for resources within the household).

For the analyses, we have identified three differentiated sub-periods at the demographic (different stages of the demographic transition) and socio-economic level: (1) 1835–1909, the period before the beginning of the fertility transition in the area of study, based on a traditional agrarian economy and characterised by some important agricultural crises (such as the agricultural depression of the 1880s); (2) 1910–1939, the period of the fertility transition; these generations corresponded to the individuals who lived through the economic growth of the first decades of the twentieth century in Spain, the economic crisis of 1930s, the Spanish civil war (1936–1939) and the harsh post-war years, and (3) 1940–1977, a period of low and declining fertility and very low

[6] This category also includes individuals for whom there is no information about their occupations.

[7] Personal communication of Prof. Vicente Pinilla (Universidad de Zaragoza, Spain).

Table 2
Characteristics of the sample in relation to the average height, birth cohorts 1835–1977, 2783 observations.[a]

	Variables	Cases	%	Average height	Standard deviation
Locality of residence	Alfamén (1908)	433	15.6	166.7	4.49
	Aylés (1899)	73	2.6	165.7	7.47
	Botorrita (1907)	121	4.4	166.9	6.74
	Codos (1900)	320	11.6	162.1	3.91
	Cosuenda (1897)	297	10.6	165.6	3.70
	Jaulín (1920)	121	4.4	167.6	5.17
	Longares (1835)	571	20.5	164.2	2.58
	Mezalocha (1899)	93	3.3	166.7	6.06
	Mozota (1838)	149	5.4	165.8	4.93
	Muel (1919)	174	6.2	166.7	4.70
	Torrecilla de Valmadrid (1900)	9	0.3	164.3	14.17
	Tosos (1914)	131	4.7	166.3	5.28
	Valmadrid (1917)	12	0.4	165.7	17.03
	Villanueva de Huerva (1909)	279	10.0	166.0	3.99
Birth decade	1830s (1835–1839)	16	0.6	158.3	16.37
	1840s	50	1.8	161.4	8.14
	1850s	14	0.5	161.9	12.73
	1860s	55	2.0	161.4	7.76
	1870s	68	2.4	162.1	7.75
	1880s	70	2.5	163.4	7.02
	1890s	113	4.1	163.7	5.39
	1900s	312	11.2	163.8	3.44
	1910s	300	10.8	164.3	3.81
	1920s	561	20.2	164.5	2.71
	1930s	463	16.6	166.4	2.68
	1940s	386	13.9	167.5	3.11
	1950s	251	9.0	168.3	3.86
	1960s	113	4.1	168.8	14.81
	1970s	11	0.4	172.2	22.84
Literacy	Illiterate	133	4.8	163.7	5.48
	Literate	2433	87.4	165.9	1.43
	Unknown	217	7.8	161.4	4.27
Father's occupation	Low skills employee	1438	51.7	165.3	1.74
	Farmer	521	18.7	166.2	2.76
	Artisan	123	4.4	166.4	5.60
	Upper class	51	1.8	166.7	31.01
	Other	650	23.4	164.7	2.48
Appeal for exemption	No appeal (fit to serve)	2416	86.8	165.7	1.28
	Physical appeals	292	10.5	164.0	4.61
	Social appeals	75	2.7	163.9	6.69
Number of living siblings (>5 years.)	0-2 siblings	465	16.7	167.1	2.90
	3-5 siblings	1401	50.3	165.4	2.02
	6 or more siblings	917	33.0	164.5	2.16
Parity	1	692	24.9	166.0	2.54
	2	608	21.8	165.8	2.54
	3	431	15.5	165.3	4.59
	4	328	11.8	165.2	3.61
	5	245	8.8	164.6	4.21
	6	173	6.2	165.0	4.90
	7 or more	306	11.0	164.7	3.81
Number of epidemic crises	Zero	1960	70.4	166.0	1.64
	One	301	10.8	163.7	3.86
	Two	57	2.1	162.6	9.20
	Three	465	16.7	164.2	2.88
Number of economic crises	0–1 years	1043	37.6	165.5	2.11
	2–3 years	992	35.7	165.0	2.52
	4–5 years	454	16.3	165.9	2.94
	6 or more years	290	10.4	165.7	3.53
Percentage of deceased siblings (<5 y)	0%–24.9%	1936	69.6	166.0	1.64
	25%–49.9%	645	23.2	164.0	2.59
	50%–100%	202	7.2	163.7	4.49

[a] The characteristics of the study area (in a similar way of Table 2) for the three subperiods are presented in the supplementary online material in Tables A1, A2, A3.
Source: Parish and municipal archives of each of the reference villages and Historical Military Archive of Guadalajara.

mortality; these generations were born after the war and in later years of rapid economic growth and completion of industrialisation, improving their lives with significant medical advances.

In addition to descriptive statistics for a first approximation of the main question, we have analysed the determinants of male biological well-being (height) at age 21 using ordinary least squares (OLS) linear regressions. This has allowed us to identify the most important determinants of height. We have developed two groups of regression models (Tables 3 and 4). The first set of models focuses on sibling mortality (as a percentage) by age at death (under 1 year and under 5 years). It displays the estimation results of six statistical models. Models (1), (2) and (3) include sibling mortality in the first year of life; and models (4), (5) and (6) examine mortality before five years of age. While models (1) and (4) take the sibling mortality variable as a continuous variable (in percent), the other models categorise these percentages as described previously. We have included a variable for birth period to control for improvements in height over time for the models (1), (2), (4) and (5). On the other hand, in models (3) and (6) we have replaced the variable *decade of birth* with a continuous variable that accounts for the child mortality rate in the study area as calculated in Fig. 2. The mortality patterns in the study area were similar to those of Aragon and rural Spain as a whole (Nicolau, 2005).

In the second set of regressions, we have carried out a similar analysis, but considering only the percentage of deceased siblings who died under the age of five and splitting the analysis into sub-periods: 1835–1909, 1910–1939 and 1940–1977. In models (1) and (4) we used sibling mortality as a continuous variable, while in the rest of the models we included it as a categorical variable. In models (1), (2), (4) and (5) we have controlled for decade of birth, whereas in models (3) and (6) we have replaced it with the mortality rate in the decade of birth.

3. Results and analysis

Fig. 3 illustrates the average height as a function of the percentage of siblings who died before the age of five, showing a negative relationship between height and the percentage of deceased siblings for the whole period. Individuals whose siblings all stayed alive were, on average, approximately 3 cm taller than those who experienced the death of more than 50% of their siblings. This observed relationship serves as a starting point for our research.

To further investigate the relationship between sibling mortality and height, we have analysed the determinants of male biological well-being (height) at age 21 using ordinary least squares (OLS) linear regressions with heteroskedasticity-robust estimation. Table 3 displays the estimation results of the regression models.

With regard to the socio-economic variables, all models show that being the child of a low skilled worker (the poorest socio-economic group in the sample) had a negative impact on height. In fact, these children were more than half a centimetre shorter than the children of farmers. As in previous studies (Quiroga, 2003; Martínez-Carrión and Puche-Gil, 2009; Ayuda and Puche-Gil, 2014; Cámara et al., 2019) *literacy* seems to be positively correlated with height, with literates being on average 2 cm taller than illiterates. As we shall discuss, this variable is only interesting for the first decades of the analysis, given that at the beginning of the twentieth century literacy rates of over 90% were recorded in the study area. Health condition at 21 years of age, as measured by the *appeals for exemption*, also seems to have played a major role in height, coinciding with the findings of previous research (Ayuda and Puche-Gil, 2014; Marco-Gracia and Puche, 2021). The individuals who claimed physical problems were, on average, more than 1 cm

Table 3
Regression results. Determinants of height in the Aragonese study area, birth cohorts 1835–1977.

Dependent variable: Height at 21 years (min. 1400 mm – max. 1950 mm)							
		Under age 1		Under age 5			
Variable	Categories	(1)	(2)	(3)	(4)	(5)	(6)
Father's occupation	Farmer	(ref.)					
	Low skills employee	−6.082*	−6.245*	−6.823*	−6.259*	−6.190*	−6.730*
		(3.62)	(3.62)	(3.61)	(3.61)	(3.61)	(3.61)
	Artisan	2.133	1.685	2.370	1.540	1.795	2.514
		(6.87)	(6.87)	(6.85)	(6.86)	(6.87)	(6.86)
	Upper class	−12.446	−12.132	−13.961	−12.596	−12.800	−14.261
		(10.03)	(10.03)	(10.03)	(10.02)	(10.03)	(10.02)
	Other or unknown	−3.333	−3.901	−5.554	−3.253	−3.410	−5.04
		(4.12)	(4.12)	(4.10)	(4.12)	(4.12)	(4.10)
Literacy	Illiterate	(ref.)					
	Literate	6.088	5.522	4.481	5.948	5.532	4.429
		(6.27)	(6.27)	(6.24)	(6.26)	(6.26)	(6.23)
	Unknown	−23.439***	−23.785***	−15.731**	−22.878***	−23.478***	−15.731**
		(7.65)	(7.65)	(7.70)	(7.65)	(7.64)	(7.70)
Parity	1	(ref.)					
	2	2.964	2.892	2.620	3.222	3.100	2.758
		(3.78)	(3.78)	(3.77)	(3.78)	(3.78)	(3.77)
	3	1.521	1.103	1.831	2.260	1.935	2.532
		(4.31)	(4.31)	(4.31)	(4.32)	(4.31)	(4.31)
	4	4.435	3.585	4.119	5.474	4.825	5.194
		(4.79)	(4.77)	(4.77)	(4.81)	(4.79)	(4.78)
	5	2.809	1.613	2.114	4.191	3.038	3.292
		(5.35)	(5.31)	(5.31)	(5.39)	(5.34)	(5.34)
	6	6.694	5.517	6.609	8.333	7.314	8.070
		(6.15)	(6.12)	(6.12)	(6.20)	(6.17)	(6.16)
	7 or more	7.184	5.623	5.617	9.760	8.502	8.070
		(5.38)	(5.34)	(5.33)	(5.52)	(5.45)	(5.44)
Appeals for exemption	No appeal (fit to serve)	(ref.)					
	Physical appeals	−12.916***	−12.720***	−13.411***	−12.701***	−12.808***	−13.560***
		(4.20)	(4.20)	(4.19)	(4.19)	(4.19)	(4.19)
	Social appeals	0.511	0.311	0.899	0.815	0.246	0.849
		(8.26)	(8.26)	(8.26)	(8.25)	(8.26)	(8.25)
Number of living siblings (>5 years.)	0-2 siblings	(ref.)					
	3-5 siblings	−5.028	−5.464	−4.918	−5.750	−5.534	−4.875
		(4.08)	(4.11)	(4.10)	(4.09)	(4.13)	(4.12)
	6 or more siblings	−8.958*	−8.783*	−7.977	−11.179**	−10.898**	−9.636*
		(5.13)	(5.20)	(5.16)	(5.25)	(5.37)	(5.33)
Number of epidemic crises	Zero	(ref.)					
	One	−2.534	−2.998	−0.284	−2.015	−2.329	0.174
		(4.56)	(4.57)	(4.62)	(4.56)	(4.57)	(4.61)
	Two	−20.383**	−20.787**	−22.326**	−19.401**	−18.731**	−20.707**
		(9.26)	(9.26)	(9.19)	(9.26)	(9.27)	(9.20)
	Three	−7.784*	−8.699**	−10.316***	−6.829	−7.200*	−9.391***
		(4.33)	(4.33)	(3.95)	(4.35)	(4.34)	(3.97)
Number of economic crises	0–1 years	(ref.)					
	2–3 years	−3.182	−3.557	−4.164	−2.698	−2.804	−3.500
		(3.11)	(3.12)	(3.11)	(3.12)	(3.12)	(3.11)
	4–5 years	1.439	1.036	−2.293	2.109	2.176	−1.484
		(4.25)	(4.25)	(4.02)	(4.26)	(4.26)	(4.03)
	6 or more years	−4.127	−4.980	−9.409*	−3.344	−3.796	−8.621*
		(5.24)	(5.24)	(4.94)	(5.25)	(5.24)	(4.94)
% of deceased siblings (continuous var.)		−0.251**			−0.270***		
		(0.10)			(0.09)		
% of deceased siblings (<5 y)	00.0–24.9	(ref.)					
	25.0–49.9		−0.971	−0.479		−9.148***	−8.032**
			(3.80)	(3.79)		(3.26)	(3.27)
	50.0–100		−20.481**	−19.289**		−10.667*	−9.207*
			(8.66)	(8.66)		(5.46)	(5.48)
Birth cohort	1835–1909	(ref.)					
	1910–1939	14.851***	16.054***		13.264***	14.056***	
		(4.50)	(4.47)		(4.56)	(4.52)	
	1940–1977	39.061***	40.361***		36.661***	37.878***	
		(5.04)	(4.99)		(5.16)	(5.09)	
Mortality rate (continuous var.)				−0.180***			−0.171***
				(0.02)			(0.02)
	Intercept	1649.38***	1648.59***	1701.38***	1652.78***	1651.50***	1700.99***
Control Village		YES	YES	YES	YES	YES	YES
	Sample size	2783	2783	2783	2783	2783	2783
	Adjusted R^2	0.123	0.123	0.124	0.124	0.124	0.125

Notes: OLS estimates; *se* denotes robust standard error.
* Statistical significance at 10% level.

** Statistical significance at 5% level.
*** Statistical significance at 1% level.
Source: Parish and municipal registers, censuses and conscription and call-up records.

shorter than those who did not. This could be the consequence of a greater expenditure of energy by people with these diseases, which impaired their growth, or the consequence of a greater competition for family resources given their limitations in the labour market to earn income.

Family size also played a role in biological well-being. We have considered the total number of siblings who survived past age five, and the associated coefficients in all regressions are negative and statistically significant. Therefore, in a context of low income until the second half of the twentieth century, the dilution of family resources among all of the siblings could have reduced their growth potential (Öberg, 2017; Ramón Muñoz and Ramón Muñoz, 2017). The resources dilution theory postulates that individuals living in large families, competing for resources, would be shorter due to not consuming enough quality nutrients. This would be a force in the opposite direction of our main hypothesis (the negative relationship between sibling mortality and stature). However, both theories are compatible and, as we will discuss, our results could indicate the existence of both factors: while there was probably a resource dilution process as families grew larger, families that experienced higher mortality (and, predictably, remained of a small size) had shorter children because they invested more energy in fighting disease. As far as *parity* is concerned, it does not seem to have played an important role in the height of individuals for the whole period (however, as we will see later, our analysis of parity by sub-periods produces some interesting results).

Our main interest in Table 3 resides in the relationship between sibling mortality and height. The six models confirm the existence of a significant negative relationship between these two variables. This is true regardless of whether we consider siblings who died before the first or fifth year of life. While the continuous variable shows a highly significant negative relationship in all the cases analysed, the results of the categorical variable are reinforcing our main argument. In the case of deaths under one year, this negative relationship only appears to be significant in the case of a very high mortality (over 50% of deceased siblings). In the first year of life the highest concentration of deaths occurred in the first days after birth, in many cases due to the weakness of the new-born. Most of these deaths were non-avoidable without today's medical knowledge and modern technology. As a result, a high proportion of families (approximately 40%) lost at least one child in these circumstances. Many of these deaths were not the result of an unfavourable epidemiological or hygienic environment within the household. Therefore, low mortality rates in this first year of life do not have a significant correlation with height. However, such a correlation does exist in households with high mortality rates at later stages, when care and living conditions in the household came into play.

Models (4), (5) and (6) consider siblings who died before reaching the age of five and show a strong and significant negative relationship between the percentage of dead siblings and height. In fact, as shown by the coefficients of the categorical variable, the effect is greater as household mortality increases. The results seem to indicate that poor household living conditions not only led to higher mortality but also reduced the biological well-being of the surviving children. We believe that this is a particularly robust result, since we have controlled for various socio-economic factors, including all the effects associated with the passage of time (as measured by *birth cohort* or by *mortality rate*) such as income growth, general modernisation, improvement in sanitation services, and changes in the general hygienic and epidemiological context. In fact, all the coefficients associated with birth cohorts are positive and statistically significant. The variable that controls exclusively for the child mortality rate in the decade of birth - in models (3) and (6) - is also strongly significant, reflecting a negative relationship between height and the periods of high mortality. Therefore, we believe that the estimated coefficients for sibling mortality -which remain statistically significant whether controlling for *birth cohort* or for *mortality rate*-reflect the individual background of diseases and health problems experienced *within* the household. These backgrounds were highly related to the provision of an adequate diet, hygiene knowledge (and its application), exposure of children to animals and pathogens, and general parental care (both routine and short-term care in the event of illness). Individuals who had more deceased siblings could have experienced a more hostile environment, either hygienically or epidemiologically, which forced them throughout their crucial life stages to spend more energy on fighting disease and less on growing (Bogin et al., 2018). This environment was affected by parental care, which in this way was probably a decisive factor in the health of children and the stature they attained in adulthood.

Table 4 shows the estimation results of various models in which only siblings who died under the age of five have been considered. The estimation of models for different periods allows us to see that, at least from the 1910s, being the child of a low skill employee had a negative impact on biological well-being. The regressions also show that the effect of alleged physical problems loses its significance in the subperiod 1940–1977. Moreover, models (1) and (2) show an interesting result for the subperiod 1835–1909: as parity increased, there was also an increase in height. The fact that this result is unique for this subperiod may be due to the low living standards in the area of study during the nineteenth century (Marco-Gracia and Puche, 2021). Generally, individuals married at a young age with low incomes, and their economic situation eased in the following years. Therefore, individuals in high parities may have been born into nuclear households with slightly higher incomes and more experience in child rearing, which may have been beneficial to their growth.

In Table 4 we are particularly interested in the results related to the mortality of under-five-year-olds experienced by siblings. The results show that there was a strong negative relationship between this mortality and height in the first two subperiods (1835–1909 and 1910–1939), which was no longer significant in the last subperiod (1940–1977). Therefore, our findings are consistent and coherent with Spain's economic and health modernisation (Nicolau, 2005; Maluquer de Motes, 2014; Pérez-Moreda et al., 2015; Prados de la Escosura, 2017). During this period, two complementary processes took place which could have favoured the reduction of mortality experienced by families. On the one hand, there was a sustained increase in the GDP per capita in Spain, hygienic knowledge was improved, and health commissions were set up at a local level in the rural environment from the end of the 1920s which imposed hygiene measures such as street cleaning. Furthermore, medical advances (such as penicillin) were made and disseminated. On the other hand, the fertility transition was also taking place, causing high birth rates (between 6 and 7 children on average per complete family) to fall to an average fertility that was slightly above replacement level in the last subperiod (Marco-Gracia, 2018). These changes reduced mortality within families, strongly reducing deaths due to digestive diseases (linked to bacteria that may have been present in a poorly sanitised house) and even their incidence and effects in the medium and long term. In addition, the lower number of children favoured a greater individual investment in offspring, improving their biological well-being and survival. In short, the mortality experienced within families ceased to be a useful indicator of parental care and practices within the families, since child deaths were prevented thanks to those general improvements.

The models only explain between 4% and 11% of the observed changes in biological well-being, which is the norm in most studies on the historical determinants of height. This could be due to several factors, including the sample size (especially in some variables with many

Table 4
Regression results. Determinants of height in the Aragonese study area, birth cohorts subperiods 1835–1909, 1910–1939 and 1940–1977.

Dependent variable: Height at 21 years (min. 1400 mm – max. 1950 mm)							
		1835–1909		1910–1939		1940–1977	
Variable	Categories	(1)	(2)	(3)	(4)	(5)	(6)
Father's occupation	Farmer	(ref.)					
	Low skills employee	−3.681	−2.783	−9.382**	−9.559**	−14.782*	−14.249*
		(7.11)	(7.07)	(4.43)	(4.45)	(8.15)	(8.14)
	Artisan	−3.054	0.443	2.745	1.690	−9.432	−8.862
		(14.48)	(14.34)	(9.84)	(9.89)	(13.47)	(13.46)
	Upper class	59.687*	62.056*	33.028	31.350	−36.504	−36.953
		(35.53)	(35.28)	(21.08)	(21.20)	(15.34)	(15.36)
	Other or unknown	−2.246	−1.376	−5.629	−8.284	−5.073	−2.735
		(7.40)	(7.36)	(5.17)	(5.16)	(11.86)	(11.75)
Literacy	Illiterate	(ref.)					
	Literate	7.688	6.592	4.482	5.502	10.207	12.256
		(7.25)	(7.18)	(9.35)	(9.40)	(59.91)	(59.91)
	Unknown	−16.273	−16.986**	2.969	1.118	–	–
		(10.08)	(8.18)	(21.22)	(21.33)		
Parity	1	(ref.)					
	2	10.818	11.298	4.310	5.822	−6.760	−6.985
		(7.55)	(7.46)	(5.30)	(5.31)	(7.94)	(7.94)
	3	14.587*	15.504*	6.104	8.370	−20.489*	−18.812*
		(8.04)	(7.98)	(6.05)	(6.02)	(10.20)	(10.06)
	4	20.889**	20.523**	0.911	3.462	−9.946	−8.029
		(8.60)	(8.43)	(6.71)	(6.64)	(12.96)	(12.81)
	5	26.911***	26.118***	−0.113	2.617	−20.582	−17.206
		(9.03)	(8.90)	(7.37)	(7.24)	(17.43)	(17.03)
	6	28.852***	27.461**	3.704	8.284	−11.110	−8.528
		(10.73)	(10.58)	(8.11)	(7.94)	(21.93)	(21.71)
	7 or more	29.917***	28.958***	6.733	9.850	−11.788	−8.136
		(9.11)	(8.95)	(7.87)	(7.60)	(22.50)	(22.20)
Appeals for exemption	No appeal (fit to serve)	(ref.)					
	Physical appeals	−7.040**	−8.778**	−23.358***	−23.577***	0.544	1.089
		(7.03)	(6.94)	(5.82)	(5.86)	(10.43)	(10.40)
	Social appeals	−27.645	−29.784	12.626	12.737	−42.141	−40.614
		(11.55)	(11.47)	(10.23)	(10.30)	(32.24)	(32.35)
Number of living siblings (>5 years.)	0-2 siblings	(ref.)					
	3-5 siblings	−6.940	−6.571	−11.725*	−16.291**	3.629	2.951
		(9.58)	(9.68)	(6.34)	(6.29)	(7.74)	(7.79)
	6 or more siblings	−18.013*	−16.866	−7.376	−14.381*	−15.071	−16.213
		(10.36)	(10.73)	(8.13)	(7.97)	(13.12)	(13.24)
Number of epidemic crises	Zero	(ref.)					
	One	8.629	8.596	−1.955	−6.138	–	–
		(5.88)	(5.57)	(7.03)	(6.99)		
	Two	−16.667	−15.641	−21.306**	−24.434**	–	–
		(16.73)	(16.67)	(10.11)	(10.13)		
	Three	6.416	5.489	−4.802	−8.973*	–	–
		(9.36)	(9.22)	(5.05)	(4.96)		
Number of economic crises	0–1 years	(ref.)					
	2–3 years	−6.454	−5.035	−1.943	0.272	−0.355	−0.644
		(5.62)	(5.25)	(5.01)	(4.97)	(7.72)	(7.49)
	4–5 years	−8.461	−7.039	0.856	6.831	12.272	12.681
		(11.53)	(10.51)	(6.10)	(5.80)	(13.18)	(13.14)
	6 or more years	–	–	−0.658	4.096	1.861	2.505
				(6.96)	(6.71)	(16.98)	(16.97)
Mortality rate by decade (continuous var.)		−0.517***	−0.051	−0.298***	0.015	0.369	−0.164**
		(0.13)	(0.06)	(0.11)	(0.07)	(0.28)	(0.08)
% of deceased siblings (<5 years)	00.0–24.9	(ref.)					
	25.0–49.9		−20.327***		−10.439**		6.491
			(5.11)		(4.22)		(10.58)
	50.0–100		−19.575**		−14.293*		17.359
			(7.65)		(7.48)		(21.57)
Decade of birth	1830s	(ref.)					
	1840s	26.088					
		(17.27)					
	1850s	27.579					
		(22.52)					
	1860s	20.331					
		(17.52)					
	1870s	26.036					
		(17.34)					
	1880s	18.071					
		(19.12)					
	1890s	28.745					
		(18.09)					
	1900s	26.272					

(*continued on next page*)

Table 4 (*continued*)

Dependent variable: Height at 21 years (min. 1400 mm – max. 1950 mm)						
	1835–1909		1910–1939		1940–1977	
	(17.84)					
1910s	(ref.)					
1920s			−2.468			
			(5.30)			
1930s			13.271**			
			(6.52)			
1940s					(ref.)	
1950s					10.540	
					(7.16)	
1960s					17.128*	
					(9.82)	
1970s					45.474*	
					(26.33)	
Intercept	1619.09***	1657.05***	1664.43***	1665.54***	1679.84***	1698.18***
	(21.20)	(22.65)	(12.44)	(17.40)	(60.34)	(60.77)
Sample size	698	698	1324	1324	761	761
Adjusted R^2	0.099	0.098	0.059	0.048	0.031	0.029

Notes: OLS estimates; se denotes robust standard error.
* Statistical significance at 10% level.
** Statistical significance at 5% level.
*** Statistical significance at 1% level.
Source: Parish and municipal registers, censuses and conscription and call-up records.

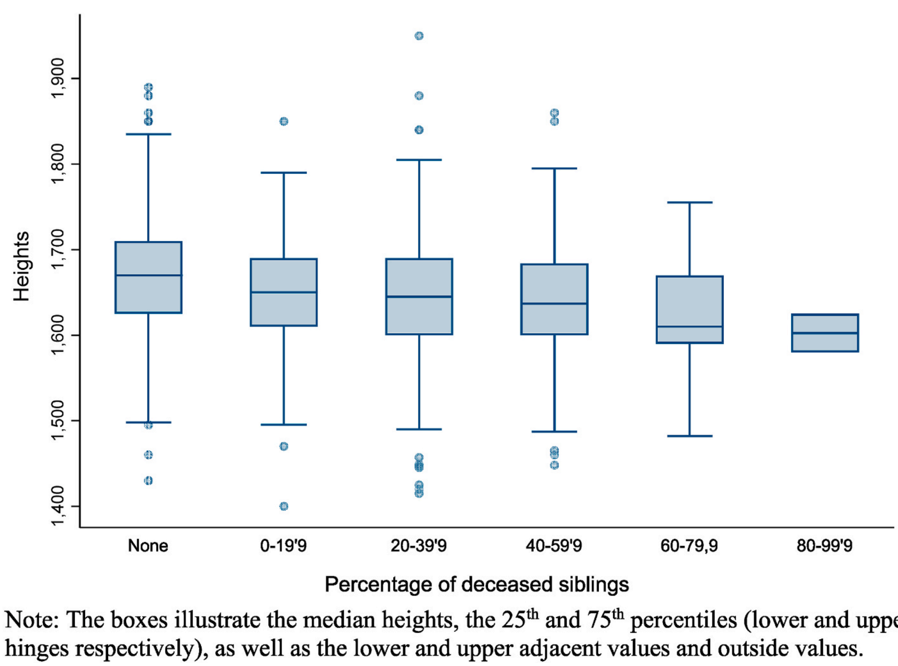

Fig. 3. Average heights according to the percentage of the total number of siblings who died before the age of five, 1830s–1970s. Note: The boxes illustrate the median heights, the 25th and 75th percentiles (lower and upper hinges respectively), as well as the lower and upper adjacent values and outside values.
Source: Parish registers of death and conscription and call-up records.

categories) and the unavailability of other explanatory variables such as the height attained by parents (which may be related to the intergenerational transmission of the epigenetic impact of living conditions on genome, see Bogin, 2020).

4. Conclusions

The relationship between the height of a generation and the infant mortality (or childhood mortality) that it experienced has been a subject of debate in recent decades. While some authors have found a strong correlation between these variables (Schmidt et al., 1995; Bozzoli et al., 2009; Hatton, 2011, 2014; Spijker et al., 2012; Coffey, 2015), others have found no or only a very weak relationship (Deaton, 2007; Akachi and Canning, 2010; Öberg, 2015). The aim of this paper has been to analyse the effects of infant and childhood mortality on heights from a new perspective, based on the sibling mortality experienced *within* the household. In this way, we have linked the epidemiological and general health context of the area with hygiene and care efforts within the family. Drawing on this information, we have been able to analyse the role of the family and its effect on the height of the children within a changing epidemiological context.

This article shows that there was a negative relationship between sibling mortality and heights well into the twentieth century. This relationship disappeared for those born in the subperiod between 1940 and 1970, when Spain's economic development soared, and the living conditions in the country improved. This result is important because it illustrates that not only the epidemiological, hygienic and general health context influenced the development of children: the situation at home (in terms of care and hygienic conditions) may have been a decisive factor in their biological well-being.

Author statement

Both authors have contributed equally to the development of the article. The population database was developed by Francisco J. Marco-Gracia, but both authors have contributed to have access and incorporate to the dataset the height data and to develop the idea, the paper and the revision of the article. Therefore: **Francisco J. Marco-Gracia:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing. **Ángel Luis González Esteban:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Resources; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2021.114394.

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