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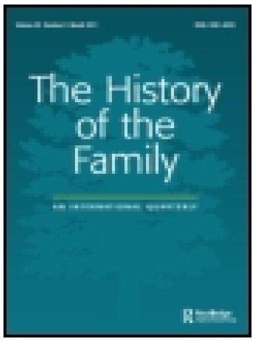

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The relationship between family characteristics and height in Sardinia at the turn of the twentieth century

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ABSTRACT

This paper is intended as a contribution to the debate on the determinants of physical stature in the past and it specifically investigates whether, in Sardinia, height – considered as a proxy of the share of household resources allocated to a child's growth – was influenced by the number of brothers and sisters amongst whom parents had to distribute available resources. This study is limited to the male population, because military records represent the only source at our disposal providing historical data on height. The community studied is the town of Alghero, located on the north-western coast of Sardinia, at the turn of the twentieth century. We have adopted a longitudinal approach, thanks to the rich dataset reconstructed for Alghero, using different sources including family, socioeconomic and anthropometric indicators. The results, in line with the resource dilution hypothesis, show that competition within the household was of some importance and that the effects on height due to scarcity of resources were particularly evident amongst farmers, the most representative socioeconomic status group in Alghero. A significant contribution to the stature reached in adulthood was also given by the socioeconomic status of the family or else by other individual characteristics.

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Height; birth order; sibship size; Sardinia

1. Introduction

There are numerous studies identifying human height as a result of well-being and living conditions during childhood (Alter, 2004; Deaton, 2007; Steckel, 1995). Many Italian studies have made use of an important source, namely military records (Arcaleni, 1998, 2012; Costanzo, 1948; Fubini, Masali, Eynard, & Salis, 2001; Sanna, 2002). These documents contain – only for the male population – a formidable set of anthropometric data (height, thoracic circumference, health status, physical traits) and sociodemographic information (date of birth, occupation, literacy) covering the whole Italian territory for the cohorts born between 1842 and 1980 (Arcaleni, 2012). These studies have allowed scholars to reconstruct

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the historical trends of heights in considerable detail, as well as to detect wide regional differences in the country.

In various countries, attention has also been paid to the inequalities between groups, and a significant role in determining such disparities has been attributed to hygiene, family and occupational characteristics (Peck & Lundberg, 1995; Silventoinen, 2003; Tanner, 1992). Recently, anthropometric data have been combined with individual biographies. This approach has attracted considerable interest (Alter & Oris, 2008; Breschi, Manfredini, & Mazzoni, 2010; Manfredini, Breschi, & Mazzoni, 2010; Öberg, 2015) and it has been successful in enhancing the opportunities offered by original sources thanks to the wealth of information on the individual, on his family and on the community in general.

In this paper, we have combined data from military sources (essentially the individual's height and education recorded at the age of 20) with other detailed information, obtained by nominative record linkage, on both the individual and his family: birth order, whether parents and siblings were alive during childhood and socioeconomic status (SES). In particular, in this paper, we have examined the individual biographies of the male cohorts born between 1866 and 1895. We have assumed the height recorded at the age of 20 as the outcome of individual well-being and living conditions during childhood.

At the time of this study, Alghero was still immersed in a pre-transitional demographic regime. The community belongs to a Region – Sardinia – which has always shown very peculiar demographic, sociocultural and even genetic features within the Italian territory.

2. Theoretical background

Especially in the past, the first-born children in large families experienced very different conditions from the later born. Such a scenario would go along with a reduction in the resources available to the family, but also with growing risk of death in early life (Elliott, 1992; Modin, 2002) and, more generally, with a decrease in quality of life: for example, a high number of children is often associated with low educational attainment (Blake, 1981, 1985; Downey, 1995; Marteleto, 2010; Steelman, Powell, Werum, & Carter, 2002). In recent years, moreover, great interest has been focused on the relationship between birth order and height, used as a marker of the quantity and quality of available resources (Eveleth & Tanner, 1990; Peck & Lundberg, 1995; Silventoinen, 2003; Tanner, 1992). There are many examples in the literature: Horton (1988), using a sample of children in the Philippines, found a strong negative effect of birth order on height. Li and Power (2004) find that the heights of children at the age of seven in Britain were negatively related to birth order but also to the number of younger siblings. Behrman (1988) highlighted that birth order is crucial in the allocation of nutrients to children in rural India. However, there are also contrasting results: Alter and Oris (2008), for instance, found a positive relationship between birth order and stature among conscripts in Belgium in the nineteenth century.

Family size is also a fundamental parameter, because higher birth order generally corresponds to larger family size. Scholars have pointed out the presence of a negative relationship between family size and stature. In the case of British children born in the 1930s, Hatton and Martin (2009) have shown that poor economic conditions, family size and the degree of crowding negatively affected stature in adulthood. A British study based on a larger sample of individuals born at the end of the twentieth century has shown that even height in the early stages of childhood was affected by the number of brothers and sisters, regardless of the socioeconomic status of the family (Lawson & Mace, 2008). Liu (2014), with reference to China, has found a negative effect of sibship size on height, but no effect was found on educational attainment. This negative association, however, may not be constant over time, and it can actually change as a result of new economic and demographic conditions, and weaken – or even disappear – if the determinants of this relationship, such as limited resources, should cease, for instance when families' income significantly improves (Marteleto & de Souza, 2012; Öberg, 2015).

The resource dilution model can explain these relationships (Blake, 1981, 1985; Downey, 1995). According to this theoretical model, parents possess limited resources for their children and, as the family size increases, there is inevitable dilution of the resources allocated to each child, which decrease as an inverse function of the number of children. Hertwig, Davis, and Sulloway (2002) have formalized the *equity heuristic model*, a variant of the original resource dilution model. According to this variant, in the presence of limited and constant resources available to the parents, as the family size increases, the degree of inequity in resource distribution amongst children inevitably rises. This inequity especially affects middle-born children. The reason is simple: they never have the opportunity to be the only child in the family at any time in their lives. In contrast to middle-born, last-born children would benefit from another advantage: when parents – especially mothers – reach the end of their reproductive period of life, the last-born will represent the last child they will ever have. The parents tend to increase – as much as possible – their efforts for the last-born, the 'baby' of the family, the last piece of family history (Salmon & Daly, 1998).

More generally, if the dilution of resources results in worse living conditions for some children, especially due to lower quality and smaller amounts of food (Horton, 1988), less investment and more limited quantity of parental time (Lindert, 1977; Price, 2008) dedicated to them, this theoretical model could explain differences in the quality of life within the family.

For the community of Alghero – the case study examined here – characterized by a large presence of nuclear families mostly in poor economic conditions with limited resources – often resulting in insufficient diet – the hypothesis of a negative association between height and number of resource competitors inside the family appears more than plausible.

3. The study area

Alghero is a relatively large (with respect to the average regional size) coastal town in north-western Sardinia (Figure 1). The town was fortified by the Doria family at the beginning of the eleventh century, but around the middle of the thirteenth century, it was conquered by the Kingdom of Aragon and transformed into a Catalan colony. In 1720, the Sardinians regained control of the city (Brigaglia, Mattone, & Melis, 1982), although some cultural Catalan traits became typical of the town, such as the dialect of Alghero – *Algherese* – which is an Eastern Catalan variant.

Before the Italian unification, in 1861, Alghero belonged to the Kingdom of Sardinia, along with the Piedmont and Liguria Regions. The first Italian census (1861) records Alghero as having 8831 inhabitants, making it the fourth largest municipality on the island. In addition to the town, the municipality included the 'Nurra', a vast area which was marshy and barely inhabited until the 1920s–1930s, and which gave Alghero a certain degree of geographical isolation. The nearest large centres were Sassari, the capital of the Province, about 35 km

Figure 1. Geographical location of Alghero.

away, and Villanova Monteleone, located on the adjacent hills, at a distance of 25 km. While there were a number of smaller communities nearby (such as Olmedo and Putifigari), their population rarely exceeded a few hundred.

Farming and sheep-farming were the prevailing socioeconomic activities in Alghero, which, considering its proximity to the sea, might seem unusual. However, this is not the case for Sardinia, where maritime economic activities were traditionally underdeveloped (Sori, 1973). There was also a small (about 5% of the labour force) but relevant 'elite' and a number of non-manual workers (Breschi, Esposito, Mazzoni, & Pozzi, 2014; Mazzoni, 2013). Even if the municipality's borders were relatively extended, for a long period of time the majority of the population lived inside the ancient centre, with obvious hygiene problems, due to the town's poor conditions.[1] In the 1921 census, almost 90% of the population of the city lived in the old city centre and, as elsewhere in Sardinia, more than 75% of Alghero population was almost completely illiterate (Breschi, Esposito, Mazzoni, & Pozzi, 2013). Compared with the inland municipalities in Sardinia, Alghero was better served with medical care, although this was defective and insufficient (Gatti, 1999; Putzolu, 1993). According to the National Survey of hygiene conditions of Italian municipalities conducted in 1885 by the General Directorate of Statistics (MAIC [Ministero di agricoltura, industria e commercio], 1886), Alghero could count on doctors, pharmacists and midwives. There was a contract between the municipal authorities and the local hospital, administered by the '*Congregazione della Carità*', for the treatment of indigent citizens who, according to the municipal historical archive, accounted for around 40% of families.

Life expectancy at birth in 1871–1872 in the Province of Sassari (which includes the municipality of Alghero) was around 30 years for both sexes, remarkably two years lower than the national average (Del Panta, 1998). In 1920–1921, life expectancy reached 47 years, with an even more pronounced gap from the rest of Italy: 2.5 years less for men and over four years for women. The peculiarity of Sardinian health transition was probably due to the endemic presence of malaria and the increased diffusion of tuberculosis, conditions that contributed to high levels of mortality among young adults (Cau, Merella, & Pozzi, 2007; Pozzi, 2000; Tognotti, 1996). Several medical surveys (Corbia, 1934; Maggiore, 1926; Pergola, 1935), carried out in the early twentieth century, document not only the diffusion of tuberculosis and malaria but also the very high incidence of other poverty-related diseases, like trachoma, especially amongst children (Melis & Pozzi, 2010, 2013).

Alghero followed the population dynamics of Sardinia, a Region that experienced the slowest and most gradual fertility transition in Italy (Livi-Bacci, 1977); the island's decline in fertility had been slow, and full transition was completed as late as the 1970s. The city, as the rest of Sardinia, showed a marked delay compared with other Italian Regions, with some small signs of fertility control by a small elite group, which was totally absent in the most rural parts of Sardinia (Breschi et al., 2014).

At the turn of the twentieth century, in fact, the total number of children remained substantially unchanged (7.5 per woman). Our previous paper, not yet published, confirms that the evolution of fertility, on the one hand, and persistent infant mortality rate on the other, ensured that the family size remained stable. In particular, thanks to prolonged breastfeeding practices (Coletti, 1908; Gatti, 2002; Pozzi, 2000), infant mortality was relatively low. Between the mid-nineteenth century and the end of the century, infant mortality – generally considered a good predictor of adult height (Quintana-Domeque, Bozzoli, & Bosch, 2011; Spijker, Cámara, & Blanes, 2012) – and child mortality decreased at a very modest rate (Mazzoni, 2013).

In Sardinia, the nuclear family was the prevailing pattern (Barbagli, 1990; Oppo, 1990; Viazzo, 2003). Indeed, in the 1921 census, 77% of the families in Alghero were nuclear and the remaining were extended (12%), while solitary individuals accounted for 6% and other family forms amounted to about 5% (Mazzoni, 2014). The peculiar features of Sardinia are not limited to this demographic history but also involve social aspects, such as late marriage and neo-locality (Barbagli, 1990), which make the island appear to be the least Mediterranean Italian Region, even though it is situated – paradoxically – in the centre of the Mediterranean Sea (Viazzo, 2003).[2]

4. Data and methods

4.1. Civil records and military lists

The demographic data used in this study have been taken from the civil records of birth, death and marriage, which were introduced in Sardinia in 1866 as decreed by the newly unified Kingdom of Italy. The civil data have been linked to information taken from military lists by means of nominative linkage techniques. The military records consisted of an extraction list and a conscription list (Cau et al., 2007). The extraction list, which was based on the population register of the municipality of Alghero, included all living males aged 20 and resident in the municipal territory. Everyone who was identified for call-up had to undergo a medical examination. The conscription list consisted of the same individuals, with the exception of a certain number of draft dodgers and inmates – around 9%, a value in line with the national ones (Corsini, 2008) – as well as of a larger number of individuals selected for the Navy National Service, which accounted for 22% of the total recorded in the extraction list. In this study, we have used the conscription list for the 1866–1895 birth cohorts. For each individual undergoing a medical examination, his height and other individual data were reported (Breschi et al., 2010; Cau et al., 2007; Manfredini et al., 2010).

All the nominal data reported in the civil registers (for the years 1866–1935) and military records (for the birth cohorts 1866–1895) were digitalized. We have excluded the last cohorts of the nineteenth century (1896–1900) from this study, because, in those years, conscripts were called for the medical examination at an earlier age, like everywhere else in Italy, as a consequence of World War I (Arcaleni, 2012; Cau et al., 2007; Costanzo, 1948). A family reconstitution has been carried out based on all the first marriages cohorts married in Alghero between 1866 and 1895 and therefore observed between 1866 and 1935. We have opted to consider only first marriages with at least one male sibling on the conscription list.

This selection comprises 1018 males, about 1.6 males per linked family. For each male examined, his family history can be obtained, in terms of composition and the destiny of siblings born, the demographic characteristics of the parents and the socioeconomic status of the father. The height and literacy (literate, illiterate or unknown) at age 20 are included in the military list. The sample derived by linking our two sources represents more than 50% of the total males that were examined for the 1866–1895 birth cohorts.

The information regarding the SES has been stratified into occupational groups, coded according to the Historical International Standard Classifications HISCO (Van Leeuwen & Maas, 2011; Van Leeuwen, Maas, & Miles, 2002) and divided into four groups: lower skilled and unskilled, farmers, skilled and elite.[3] The first group (HISCLASS 9 to 11) consists of labourers and quarrymen and very few fishermen. The reason is to be found in the particular characteristics of the conscription list and in the lack of individuals destined for the Navy National Service. The second group (HISCLASS 8) is the most representative of Alghero and consists of farmers and shepherds, having an agro-pastoral connotation and representing the most Sardinian trait of Alghero. The skilled group (HISCLASS 7) includes bricklayers, artisans and other workers with some form of vocational skills. The latter group (HISCLASS 1 to 6) consists of individuals linked to local public administration services (employees, clerks) and a small portion consisting of individuals engaged in professions (doctors, pharmacists, teachers). The sample is represented in Table 1 and can show a good degree of social stratification reflecting, with some dissimilarity, the local scenario.

4.2. Methodology – correcting the birth order

To test the hypothesis that lower stature was associated with increasing birth order and family size, we have opted for a solution combining these two variables in a single parameter and, therefore, limiting correlation effect.

Table 1. SES stratification of the sample by HISCLASS. Alghero (1866–1895 birth cohorts).

Socioeconomic status	HISCLASS	*N*	%
Lower skilled and unskilled	9–11	197	19.4
Farmers	8	642	63.1
Skilled	7	114	11.2
Elite	1–6	65	6.4
Total	1–11	1018	100.0

Sibship size can be measured in several ways, for instance considering the total number of births, the number of surviving children, or the average number of children during a certain phase of an individual's life. This last method is more consistent with the resource dilution model and is similar to the one used by Öberg (2015). It consists of a time-weighted average number of children measured during an individual's childhood.

For each conscript, we have built a score denominated Ψ that represents his sibship size during childhood. The score contains a contribution of 0.1 for each year lived from birth to the age of 10 years, and it includes the observed individual. A boy that is the only child in the family, for example, will have a score of 1, but if he has a twin who survives until the age of 10, his score will be 2. Each sibling that crosses the individual's life from birth to 10 will contribute to the score. The 10-year timeframe corresponds to a phase of life during which an individual is more dependent on his parents. After the age of 10, we assume that the individual is able to provide some resources to his family by starting to work (inside the family or for others), thus contributing, at least in part, to his own livelihood.

Figure 2 represents the variation of Ψ as a function of the birth order and outlines a concave curve in correspondence with the central positions in the family, that is to say, where competition, due to a larger sibship size, is higher.[4]

In addition to the Ψ score described above, we built a second score, Ψ_{max}, which does not take account of the mortality of siblings and thus represents the potential sibship size, as if none of the siblings had died during the 10 years window of the infancy of the measured conscript. The ratio between the two scores (Ψ/Ψ_{max}), called δ, will be equal to 1 where none of the siblings died, and will be lower than 1 where one or more siblings died within the 10-year timeframe. In our sample, δ assumes values between a minimum of 0.4 and a maximum of 1.

Finally, we have calculated the 'corrected birth order' (hereinafter c.b.o.), obtained by multiplying the birth order by *δ*. In short, the birth order is downgraded when not all the siblings actually compete for resources and it remains unchanged when siblings survive.[5] Using the birth order without correction, in fact, we would take the risk of giving the same weight, for instance, to a third-born in a family with all the children surviving and to a third-born in a family where several children died and did not participate in the resource competition. Using only Ψ could lead, instead, to giving the same weight to individuals belonging to very prolific families, but with many children who died, and to individuals belonging to families with few children but all surviving.

Therefore our c.b.o. is able to take into account the birth order but at the same time makes it possible to give different weights to individuals having experienced very different family histories in term of sibship size during childhood.

In addition to this variable, the presented models contain a specific covariate in order to test the hypothesis that the last-born child not only might have experienced less competition

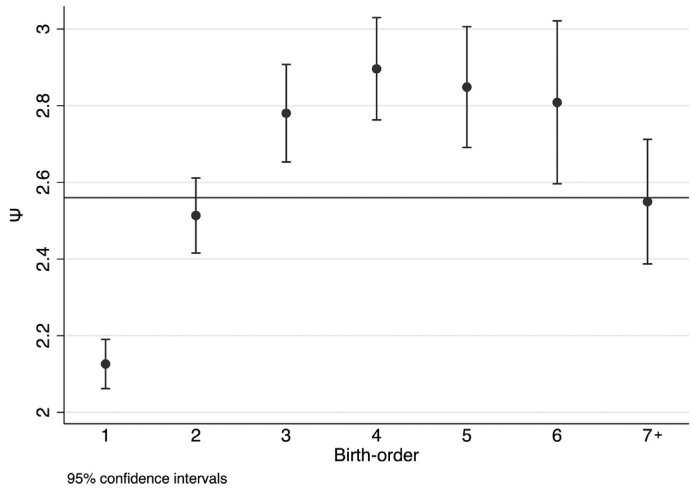

Figure 2. Ψ score and confidence intervals by birth order. Alghero (1866–1895 birth cohorts).

but might have received more care (amount and quality of food and time) from his parents and possibly also from older siblings able to contribute, at least in part, to the family's resources.

To separate the effects of different components that can affect the height of measured males, we propose a hierarchical linear model (also known as multilevel model or mixed linear model) able to account for the fact that each individual is nested in a household (see Osborne, 2000 for a discussion of the advantages offered by this statistical technique). It is obvious that individuals belonging to the same household will share some characteristics (for instance genetic factors, but also economic and social conditions), thus, the observations referring to these individuals will not be independent. A hierarchical linear model can take account of the partial interdependence of individuals belonging to the same family, thus improving statistical inference with respect to ordinary least squares (OLS), where the standard errors will be downward biased because of the violation of the error independence hypothesis.[6]

The dependent variable is the height in centimetres; our main right-hand side variables are c.b.o. and a last-born dummy. To exclude any possible estimation bias due to omitted variables, we have included also other individual covariates derived from the nominative reconstruction (family SES, presence/death of the parents during childhood) and literacy of the individual.

5. Descriptive results

The mean height of the 1018 young men that were born in Alghero during the 1866–1895 period and were measured at the enrolment examination, at the age of 20, was particularly low (about 158.5 cm). This value is in line with other reports for the Sardinian male population in the sources of the time and in various studies (Arcaleni, 2012; Gatti, Calò, & Piras, 2008; Giuffrida-Ruggeri, 1918), attesting that Sardinian men were the shortest in the Kingdom.

Table 2. Mean height by birth cohort (1866–1895) in Alghero.

Birth cohort	*N*	Mean height (cm)	Standard error (cm)	95% C.I.	
1866–1875	187	158.8	0.5	157.7	159.8
1876–1880	194	158.3	0.6	157.2	159.4
1881–1885	236	158.0	0.5	156.9	159.0
1886–1890	218	158.7	0.5	157.8	159.6
1891–1895	183	158.0	0.6	156.8	159.0
1866–1895	1018	158.3	0.2	157.9	158.8

The value measured for Alghero returns a negative difference of about 5 cm in comparison with the mean national height reported by Costanzo (1948).

This short stature was responsible for the very high number of examined males (23%) who did not reach a height of 154 cm (Cau et al., 2007).[7] Across the birth cohorts under examination, no increase in mean height can be detected (see Table 2). The stature of the examined individuals shows a downward trend up to 1891–1895, with the average diminishing from 158.8 cm to 158 cm, with the only exception during the 1886–1890 five-year period, when the average reached 158.7 cm. Moreover, several studies have shown the absence of any increase in height in the Sardinian male population (Arcaleni, 2012; Cau et al., 2007; Lanari, 2011; Sanna, 2002; Sanna, Floris, & Cosseddu, 1993). Indeed, at the end of the nineteenth century and even in the early years of the twentieth century, the island was far from seeing a genuine beginning of *the secular trend*.

Height is largely shaped by genetic factors (Eveleth & Tanner, 1990) and in the local context this aspect is reflected in the limited stature of the Sardinians, a population that is characterized by a particular gene pool showing a number of variants that are very rare or absent elsewhere (Francalacci et al., 2013).[8] The Catalan roots of Alghero, however, have not changed the local gene pool, according to a study that was conducted in the late 1990s of the twentieth century and showed no particular genetic differences between the local population and the rest of the island (Moral, Marogna, Salis, Succa, & Vona, 1994).

In addition to genetic factors, both for the local population and for that of the surrounding areas, a decisive role was played by poverty and insufficient nutrition: factors that can limit – especially in the early phases of life – human stature (Silventoinen, 2003). Moreover, as recently pointed out by Grasgruber and colleagues (2014), the ratio between high-quality proteins (deriving from meat) and low-quality proteins (deriving from vegetables) could become a limiting factor on height. Using the available sources of the time, Cau et al. (2007) have shown that the diet of farmers in the Alghero area was highly deficient in terms of calories.[9] Many investigations into the state of nutrition of the population were published in the first half of the twentieth century (Giusti, 1940; Niceforo & Galeotti, 1934; Peretti, 1943). These studies describe the low-calorie regime of the local population and, at the same time, the limited resources available to families: their diet was based essentially on vegetables, often consumed in a single meal per day and, more generally, largely insufficient to cover calorific requirements (Niceforo & Galeotti, 1934).

Differences were evident between socioeconomic groups and, according to the pioneering work of Ridolfo Livi (1896, 1905), the higher the social status, the taller the individual. Considering the different occupational groups (Table 3), a social gradient in the statures can be observed. In particular, the elite group shows a mean height at 20 years (164.3 cm) that is significantly higher than that of the other SES groups, while the farmers show the lowest

Table 3. Mean height by father's SES and ego's education. Alghero (1866–1895 birth cohorts).

Father's SES	All		Illiterate		Literate		Unknown	
Lower skilled and unskilled	160.4	19.4	159.0	18.2	162.2	22.6	158.8	13.0
Farmer	156.7	63.1	155.6	76.3	159.6	43.6	156.3	69.0
Skilled	160.4	11.2	159.4	4.6	160.8	20.0	160.5	12.0
Elite	164.3	6.4	161.4	1.0	164.4	13.9	165.6	6.0
Total	158.3	100	156.4	100	161.1	100	157.7	100
N	1018		528		390		100	

Note: % of column total.

mean value (156.7 cm). The other groups ('lower skilled and unskilled' and 'skilled') show a mean value of about 160.4 cm, with very little variation.

The differences in the mean height may reflect different living conditions and a disparity of resources among the groups. However, differences emerge within the socioeconomic group: individuals that, at the age of 20, were able to read and write were on average taller than illiterate ones. Amongst the farmers, those who were illiterate had the lowest height (155.6 cm), but those who were able to read and write were moderately taller, and the SES gap was considerably reduced. The opportunity to receive basic education was an advantage, following – probably – a reduced burden of work in the fields, especially at a young age, but at the same time having had this opportunity may be indicative of better economic conditions in the household to which the individual belonged.

The family reconstruction process, however, allows us to contextualize the male stature taking into account the order of birth. In our sample, the mean value of the birth order is 3.3 while its highest value stands at 12. In Figure 3, we show the average height of the 1018 males examined by birth order. Focusing our attention on the difference between the first two birth orders, we can notice that the first-born individuals show an average height that is about 0.5 cm lower. In the literature, the data on the height of the first-born are quite controversial. In certain populations, for example, the first-born are on average taller than the second-born (Al-Omair, 1991; Hermanussen, Hermanussen, & Burmeister, 1988); other scholars, although with reference to the height recorded in pubertal age in current populations, show an opposite result (Savage et al., 2013). In Alghero, the mean height always decreases as the birth order increases, with the exception of the mean height of the first-born vs the second-born, which increases. More specifically, after the second-born, we detect a constant decrease in the average height until the fifth. For the sixth-born, it is possible to appreciate a slight rise, and for the seventh-born and following orders there is an increase in the average height.

Even if the calculated confidence intervals are quite wide, the scenario suggests a negative relationship between birth order and height with some recovery for those born with order seven and plus. Considering the average number of children born per family in Alghero (about seven in every SES group), the seventh and plus order will likely include last-born children, who, for the reasons discussed above, may have an advantage (in terms of resource going to them) with respect to their older siblings. Thus, our expectation on the sign of relation between the c.b.o. and height is negative, but, at the same time, we surmise a partial recovery for the last-born children. In the next section we will proceed to a multivariate approach that uses both individual and family variables.

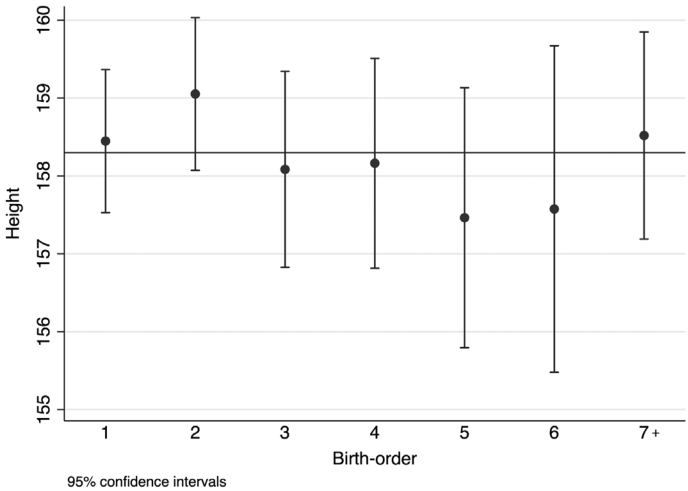

Figure 3. Mean height and confidence intervals by birth order. Alghero (1866–1895 birth cohorts).

6. Individual and family perspective

The statistical analysis refers to 1003 individuals corresponding to those young men whose families included at least two children.[10] Table 4 shows the results of the above described models: the first model takes account of the information regarding family composition in terms of c.b.o., last child dummy and presence/death of the parents, while the second and third models introduce the socioeconomic status of the family and the individual's level of education.

The results of the first model (Model 1) show, as expected, a negative and statistically significant relationship between c.b.o. and height (coefficient: –0.240), indicating that stature diminishes by 0.2 cm as c.b.o increases by one unit. At the same time, the covariate referring to the last-born child is positive and statistically significant, with a coefficient amounting to almost 2 and empirically confirming the hypothesized advantage of being the last-born child.

The negative association between the c.b.o. and height remains also in Model 2 and Model 3, where we introduce the control variables. The association does not vary substantially in terms of direction of the relation or statistical significance.[11]

In Model 4 we repeated the analysis carried out in the previous model, but we added a further regressor: c.b.o.*Last. The latter is obtained as the interaction between being the last born and the c.b.o. The interaction term should be interpreted as follows: does the relation between height and c.b.o. vary in function of being the last born? In other words, given that the corrected birth order is equal to n_i we can measure the advantage/disadvantage of being the last born in terms of height. So, for instance, suppose that we want to compare an individual with c.b.o. = 4 who is the last born with an individual with similar c.b.o. but who is not the last born. According to the coefficients estimated in Model 4, we will have the effect of c.b.o. (–0.27*4 + 0.55*1 = –0.53) for the former and (–0.27*4 = –1.08) for the latter.

Therefore, our expectation of a weaker impact of our parameter on the height of the last born seems to be confirmed by our results.

Table 4. Regression models for height. Alghero (1866–1895 birth cohorts).

	Model 1		Model 2		Model 3		Model 4		%
	Coeff.	P>|z|	Coeff.	P>|z|	Coeff.	P>|z|	Coeff.	P>|z|	mean
Birth cohort (<1886 ref.)	1.000		1.000		1.000		1.000		60.6
1886+	0.438	0.398	0.123	0.804	0.108	0.827	0.073	0.882	39.4
Corrected birth order (c.b.o.)	**−0.240**	0.053	**−0.196**	0.099	**−0.201**	0.090	**−0.271**	0.029	3.0
Last child	**1.905**	0.027	1.306	0.116	1.231	0.138	−1.717	0.344	8.3
*Corrected birth order*Last*							**0.554**	0.068	
Presence/death of parents (Alive ref.)	1.000		1.000		1.000		1.000		80.5
Father died	**−1.830**	0.016	−0.840	0.248	−0.839	0.247	−0.815	0.261	11.7
Mother died	−1.062	0.277	−0.908	0.325	−0.874	0.343	−0.794	0.388	6.9
Both died	−2.091	0.410	−1.477	0.538	−1.604	0.503	−1.815	0.449	0.9
Family SES (Low skilled and unskilled ref.)			1.000		1.000		1.000		19.4
Farmer			**−2.901**	0.000	**−3.184**	0.000	**−3.223**	0.000	63.1
Skilled			−0.715	0.454	0.990	0.475	0.942	0.496	11.4
Elite			**3.244**	0.006	**5.264**	0.001	**5.187**	0.002	6.1
Ego education (Illiterate ref.)			1.000		1.000		1.000		52.0
Unknown			0.965	0.195	0.743	0.322	0.753	0.315	9.9
Literate			**3.008**	0.000	0.439	0.734	0.465	0.718	38.1
Interactions									
Farmer*literate					**3.222**	0.022	**3.181**	0.024	16.7
Skilled*literate					2.332	0.149	2.266	0.161	8.7
Constant	159.0	0.000	159.4	0.000	159.5	0.000	159.8	0.000	
AIC	6829.9		6736.6		6735.3		6734.0		
Prob > chi²	0.032		0.000		0.000		0.000		
Log likelihood	−3405.9		−3354.3		−3351.7		−3350.0		
Sd (Constant)	4.9		4.2		4.2		4.2		
Sd (Residual)	5.7		5.7		5.7		5.7		
Individuals	1003 (636 families)								
Examined men per family	(minimum 1; maximum 7; average 1.6)								

Note: In bold, coefficients that are statistically significant ($p \leq 0.10$).

Furthermore, it is worth dwelling on the control variables, which confirm the role of the presented variables. In addition, evaluating the reasonability of control variables is also a way to judge the general reliability of a statistical model. The birth cohort, for example, is never statistically significant in all models, a result confirming that, for the analysed years, there have been no substantial changes in height. The covariate referring to the presence/death of parents suggests that individuals whose parents died in their first 10 years of life were shorter than those whose parents were alive, although statistical significance is reached only when it was the father who died. With regard to the SES of the family (Model 2), in comparison with the reference category (lower skilled and unskilled) farmers are characterized by a negative coefficient, while a positive coefficient is recorded for the elite group. No difference is detectable, however, for the group of skilled individuals. Regarding literacy, we observe increased stature (by about 3 cm) for those young men who were able to read and write. As already mentioned, not only does this variable indicate a certain degree of individual schooling but also it suggests more favourable living conditions during childhood. Being able to afford an education for their children could be considered an indicator of well-being,

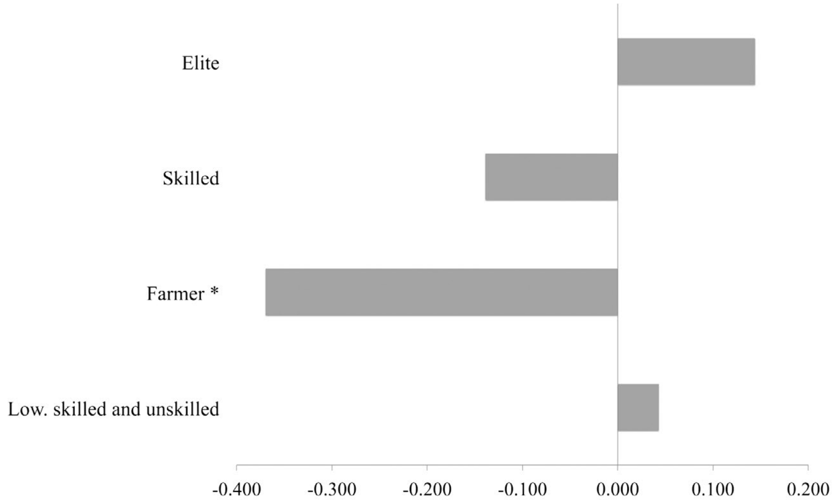

Figure 4. Corrected birth order coefficients by SES. Alghero (1866–1895 birth cohorts).
Note: coefficients with * are statistically significant ($p \leq 0.05$).

particularly for the most disadvantaged families, including farmers. The interaction models (Models 3 and 4) show that the individuals whose father was a farmer but who were able to read and write were taller, by about 3 cm, than those young men of the same socioeconomic group who were illiterate.

To check the robustness of our analysis, we calculated the models described above using, rather than c.b.o., the simple birth order and Ψ indicator. The order of birth, as well as showing a much lower magnitude, is statistically significant only in the first and last models. Similarly Ψ, although it indicates a negative relationship in each model taken into consideration, never reaches full statistical significance. These results suggest that c.b.o. can better capture the negative effect of increasing actual sibship size (and thus competition) during the crucial childhood window on height than the simple birth order.

Finally, we intended to test whether the relationship between the c.b.o. and height was present in each SES group. For this purpose, we have run separate models for each group and the coefficients of the c.b.o. are shown in Figure 4. Two groups, farmers and skilled, show a negative association between the c.b.o. and height, even if the strongest negative effect (−0.37) and statistical significance are measured only in the former case. The lower skilled and unskilled coefficient is close to zero and for the small elite group the relationship changes in direction, becoming positive, even if both models are not statistically significant.

7. Final remarks

In Alghero, belonging to a specific socioeconomic group rather than to another caused significant differences in the quality of life of the individuals. Significant differentials were found in the stature of Alghero's adult males. Although most of the population lived in the historical centre of the town, the living conditions of the farmers were far worse than those of the other social groups, since it was not so uncommon for families to cohabit – in the crowded city centre – with farm animals. The results presented in this paper – although they should obviously be considered with a certain degree of caution – show that an increase in c.b.o. index (as defined above) implied that its members were shorter although an attenuation of this effect is also observed for the last-born. The mentioned association seems to be stronger in the families of farmers compared with the other social groups considered. This result would provide further evidence for the hypothesis just formulated, and would seem to be supported by the living conditions of this particularly disadvantaged social group. The limited resources of the farmers, their poor and inadequate diet based essentially on vegetables, and their bad housing conditions, would result in a disadvantage, especially for those living their first years of life in a context of increased pressure and competition. Furthermore, the particular structure of the family – being mostly nuclear – could not guarantee any forms of external support – even if limited – so that only the parents would take care of their children from the earliest stages of life until an age when they could sustain themselves. Indeed, the family was an autonomous and almost exclusive unit of consumption (Angioni, 1990). However, one could argue that the older children remaining in the family – before their marriage – would ensure a certain amount of resources. This conjecture – though reasonable – must be considered also in the light of the fact that Alghero, as the rest of Sardinia, was characterized by a neo-local model of family formation. So, at least for that part of the population more linked to local traditions, those who wished to build their own family – separate from that of their origin – had to ensure the accumulation of the necessary resources (Oppo, 1990). Therefore, the contribution of older siblings to the resources of their families of origin could be limited by this cultural norm (especially in large families where the age difference between first-born and last-born children was large).

Notes

1. In the late nineteenth century the old town structure was radically modified following the demolition of the walls that had long protected it (Sari, 1998, 1999).
2. Another peculiarity of Sardinia consists in the existence, before the thirteenth century, of a different system of personal identification with the adoption of patrilineality and matrilineality (Murru Corriga, 2000).
3. Father's occupation has been derived from the marriage register. We decided to use the information reported in this source because a crosscheck on the dataset allowed us to consider this information as the most representative of the usual occupations in Alghero, a community where social mobility was weak or even absent (Breschi et al., 2010).
4. The average of Ψ score remains essentially stable along the birth cohorts, reaching a value of 2.5 for those born before 1886, and 2.6 for those born after that year.
5. We have included a graphical example (see Appendix 1) that shows the calculation of c.b.o. for a hypothetical individual fourth-born in a family of eight siblings.
6. A possible problem for a hierarchical linear model may be a small number of observations per cluster. The econometric literature has shown, in fact, that a small number of observations per cluster does not bias the individual level of the analysis but may influence the results associated to cluster level analysis. Clarke and Wheaton (2007) suggest, for instance, that for a correct inference, one needs at least 10 observations for 100 clusters. However, more recently Bell and colleagues (2010) have shown that, in two-level models (our model falls in this category), the bias produced in cluster level predictors is more responsive to the number of clusters than to the number of observations per cluster. In particular, they have shown that, if the analysis includes at least 500 clusters, the proportion of singletons (cluster with only one observation) has a negligible impact on the inference of level two predictors. We have more than 600 families, so our model largely satisfies this rule.

7. Cau et al. (2007) describe in detail the height limits for different periods. These limits varied, according to the regulations in force at the relevant time (1854 to 1917), by a minimum of 150 cm up to 156 cm.
8. A genetic study based on 6307 individuals has recently highlighted the association between Sardinian low height and the local gene pool, a clear example of the 'island effect' that reduces the size of large mammals (Zoledziewska et al., 2015).
9. The sources used by Cau and colleagues (2007) refer to Sassari, the capital of the Province where Alghero is located, but the authors assume that the Alghero diet was very similar.
10. We excluded 15 individuals who were the only child of a couple. Not only were these individuals always in the position of being the last-born child, but they were particularly short and therefore possible outliers.
11. The sequence of models has been tested based on the Akaike information criterion (AIC) (Akaike, 1974), with lower values indicating the progressively increased adaptation of models.

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Appendix 1.

Example of corrected birth order calculation in the case of a fourth-born (Index) in an eight-sibling family

In the example, for simplicity reasons, we consider birth intervals of two years. For each year, in a time window of 10 years, we indicate Ψ, Ψmax and the partial contributions by each sibling. In this particular case, siblings with birth order 1, 3 and 7 had died in the time window of Index, and therefore, participated only partially in the calculation of Ψ. The birth order of Index (4), due to the death of three siblings, is downgraded and results in a lower value equal to about 3 c.b.o. (4*0.771 = 3.083). In the event that the three siblings had not died, birth order and c.b.o. index would be the same (4*1 = 4).

Table A1. Example of corrected birth order calculation.

Life course events of siblings	Time	Birth order of siblings							
		First	**Second**	**Third**	**Fifth**	**Sixth**	**Seventh**	**Eighth**	
Birth first	-6								
-	-5								
Birth second	-4								
-	-3								
Birth third	-2								
	-1								
Birth fourth (Index)	0								Ten years frame
Death first	1								
Birth fifth	2								
Death third	3								
Birth sixth	4								
-	5								
Birth seventh	6								
Death sixth	7								
Birth eighth	6								
-	9								
-	10								
Death seventh	11								
-	12								
Death eighth	13								Tot.
Ψ	1 +	0.1	0.6	0.3	0.8	0.3	0.4	0.2	**3.7**
Ψmax	1 +	0.4	0.6	0.8	0.8	0.6	0.4	0.2	**4.8**
δ= 3.7/4.8 =0.771		Corrected Birth Order= 4*0.771=3.083							

Ψ annual contribution Ψmax annual contribution