Anthropometric traits at military medical examination associated with demographic family characteristics

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1. Introduction

Body parameters are fundamental anthropometric features resulting from a combination of genetic and environmental factors. More specifically, height is correlated with whealt, education, and to a certain extent, health and longevity (Schumacher, 1982; Courtiol et al., 2010; Samaras, 2012). In most Western societies more than 80% of the variation in body height is due to genetic factors (Silventoinen, 2003, Silventoinen et al., 2003). In general, the height of an adult individual results from a series of events starting during intrauterine life and continuing after birth until the age of about 20 years, when height reaches a peak followed by a slow shrink in advanced age. The factors regulating growth and body parameters are known only in part and, aside from the influence of heredity, the role of nutritional (Prentice, 2001), hormonal (Baron et al., 2015) and social factors (Hancock et al., 2015) has also been thoroughly studied. The substantial role of non-genetic factors is evidenced by observing identical twins who share the same genome but do not attain the same adult height if they have experienced different life circumstances. In general, height results from a complex and probably non-additive interaction between the genetic makeup and the environment (Tanner, 1994).

Military archives have been largely used to assess anthropometric traits and more specifically height and chest circumference in the young male population (Livi, 1883; Livi, 1896; Karpinos, 1958; Karpinos, 1961). These anthropometric traits of young men observed during military medical examination around age 20 are excellent indicators of their individual health and nutritional status, and more generally, they can reflect the net result of the historical socio-economic conditions prevailing during the growing period (Komlos 1994, Breschi et al. 2007). So far, to our knowledge, historical demographers showed little interest in the association of anthropometric traits with demographic family characteristics such as child birth order, birth spacing and maternal age. Few studies in historical demography have investigated how anthropometric traits covary between siblings in the same family and what is the possible impact of shared genetic factors and common environmental influences (Alter et al., 2008). The association of anthropometric traits and sibship size has received more consideration in historical populations who faced socio-economic difficulties (Öberg, 2015). Limited socio-economic resources within

a family may cause poorer living conditions that could result in weaker anthropometric traits in younger family members according the so-called Resource Dilution Hypothesis (RDH) proposed by Blake (1981). RDH predicts shorter height and chest circumference in conscripts belonging to larger sibships, a condition that could disappear as soon as socio-economic conditions improve (Becker 1993; Oberg 2015).

In Sardinia, numerous and accurate datasets are available in military archives spanning the past 150 years. The present contribution analyses long run data of conscripts born between 1853 and 1935 in a mountainous population of Sardinia. This island hosts an isolated founder population with peculiar genetic characteristics whose height has been the target of numerous studies covering large time periods. The study of bone characteristics of Sardinians in prehistoric times carried out in burial tombs provides height estimates of 153 cm in women and 160 cm in men (Mazzarello et al., 2010). In modern times, the analysis of military conscripts by Livi-Bacci (1986) revealed that Sardinians are on average the shortest men among all Italian regions. This trend has been confirmed by subsequent analyses that reported a shorter average stature among Sardinians conscripts compared to Italian birth cohorts for the same period (Costanzo, 1948; Cappieri 1960; Grassivaro 1972). These differences have been attributed to the influence of multiple factors, including genetic and environmental factors. As for the genetic determinants, a recent GWAS study by Zoledziewska et al. (2015) was able to identify two genetic variants (GHR and KCNQ1 genes) relatively frequent in Sardinia with major negative effect on stature. These stature-shortening variants might have been selected through the "island rule" principle stating that the size attained by members of a species living in an island depends on the resources available in the environment (Foster, 1964). In the past the harsh socio-economic conditions of Sardinia may have been important to differentiate the island from the more affluent Northern and Central Italian regions (Confindustria Research, 1989; ISTAT, 1990). The progressive increase of height, spanning more than a century, has been documented in the Sardinian population (Sanna, 2002) as in the industrialized world, where it started only one and half century ago (Grasgruber, 2014). This phenomenon can hardly be explained by a modification of the genetic structure of the population but seems to be mostly the result of the impact of improved life conditions on a substantially stable genetic substrate. Family-related factors include genetics (parental transmission of stature-modifying genes) as well as environment (magnitude and sharing of household resources devoted to children).

Chest circumference was usually one of the parameters used to assess the individual fitness for military service. It has been the subject of a smaller number of studies dealing with the nutritional and socio-economic status of the population in the past (Breschi et al. 2007). The determinants of chest circumference are less known than those concerning height. They would act primarily on the development of chest bones as well as on the thickness of the surrounding muscular component and subcutaneous adipose tissue (Silventoinen et al, 2012). The role of genetic factors controlling chest circumference are estimated around 34% while 59% would depend on common

environmental effects and 7% by specific environmental effects as demonstrated by twin studies (Chatterjee S, 1999). This implies that a greater variation in the average adult value of chest circumference in comparison to that of height in a given population would be expected, in relation to changes of environmental influences as well as of particular historical circumstances.

In Sardinia, the existence of reliable military archives and complete demographic data on families covering the last two centuries facilitates the inquiry into the temporal behavior of the two anthropometric traits under concern, as well as their association with various demographic factors of the target population. The accuracy and exhaustiveness of these archives is evidenced by their previous use in anthropological surveys.

From the above considerations, the following research questions are formulated:

(i) Are there quantitative differences in height and chest circumference, both in magnitude and temporal trends, in the conscripts of Villagrande compared with other groups in Sardinia and Italy?

(ii) Is there a significant association between anthropometric traits of conscripts and their family characteristics, namely birth rank of the child, birth spacing, maternal age and sibship size?

(iii) Are anthropometric traits of conscripts in this mountainous population of Sardinia consistent with RDH as it was demonstrated by Öberg (2015) for the Swedish population in the 19th century?

The analysis of the data collected allows to answer partially such questions and generated new insight that might facilitate future investigations in this field. In the discussion, the particular behavior of body parameters in this population has been reviewed in the light of literature data and some general assumptions related to them have been challenged. This has been an opportunity to rethink some general aspects of the population concerned and give cues as a guide for future research.

2. Setting and data sources

In this investigation we use data retrieved from the population of Villagrande Strisaili, a relatively isolated village located in the mountainous part of Ogliastra, a subregion of Sardinia, at 700 meters above sea level. Today the population of Villagrande accounts for 3,300 inhabitants mostly involved in pastoralism and nomadic shepherding and it appears as a quite egalitarian society (Poulain et al., 2011; Pes et al., 2013). Untill the 1950s, most men in the village were *pastori* (shepherds) or *contadini* (peasants) and only after WWII the community opened to the external world and experienced a strong socio-economic improvement.

The population of Villagrande is being intensively studied since it was identified as hot-spot of exceptional male longevity, more specifically a place where men live as long as women do (Poulain et al., 2004; Poulain et al., 2011). Moreover, this population

experienced fertility decline at a very slow pace, as until WWII mothers still delivered an average of six children and the mean age a woman had her last child was still above 41 years. Considering the amount of data already available to characterise the families of this population during the last two centuries as well as its specificity and relative homogeneity we have launched a systematic data collection on conscripts. On this dataset we started to investigate the association between anthromopetric traits and demographic characteristics.

2.1 Demographic data

Data extracted from the parish registers (*Quinque Libri*, since 1778), the civil registers (since 1866) and the population register (*anagrafe*, since 1931) are used to reconstruct nearly one thousand families of Villagrande, where parents had at least one boy born after 1850. A small number of families, where parents are both born outside Villagrande, are excluded as well as families that are not completed due to migrations. For every boy born in Villagrande since 1850 individual and family characteristics are fully available: the precise date of birth and death or proof of survival in 2015, the birth order, the intergenesic interval preceding his birth, the maternal age at birth, the sibship size (total number of brothers and sisters) and the number of siblings who survived at age 5.

2.2 Conscript recruiting process and available archives

On January 1st each year the *sindaco* (mayor) of each municipality was asked to provide the list of all boys born in the municipality who were expected to attain their 18th birthday during the forthcoming year. This list, termed *Lista di leva sui giovani nati nell' anno X* (enrolment list of young men born during the year X) is established yearly as a base for calling young male citizens to the medical examination. The *Lista di leva* is sent to the *Consiglio di Leva* (enrolment council) at the level of the *circondario* (military district) who verifies it and schedules for the date of medical examination. The latter usually takes place during the year of their 20th birthday, except for the classes 1895 to 1898, 1901 to 1910 and 1919 to 1923 (19th birthday) and the classes 1899, 1900, 1924 and 1925 (18th birthday) when more conscripts were requested during the two WWs. Upon the result of this medical examination individual data are included in the *Lista di leva* and the decision taken by the *Consiglio di Leva* concerning the enrolment is mentioned in the last column of this register.

Specifically, as shown on the facsimile displayed on Figure 1, these lists include three types of information:

1. The administrative information initially provided by the municipality;
2. The data on the different anthropometric traits measured during the medical examination: *statura* (height), *torace* (chest circumference), *capelli, colore e forma* (hair, colour and shape), *viso* (face shape), *naso* (nose), *mento* (chin), *occhi* (eyes),

sopracciglia (eyebrow), *fronte* (forehead), *colorito* (complexion), *bocca* (mouth), *dentatura* (teeth), *segni particolari* (specific marks), *arte o professione* (occupation).

3. The decision taken by the *Consiglio di Leva* (see below section 2.3)

This procedure as described in details by Lamioni (2002) ends up with the *Lista di Estrazione* (extraction list) completed on the base of the information mentioned in the *Lista di Leva* but concerned the whole *circondario* that for Villagrande is the *Circondario* of Lanusei. In terms of individual data the *Lista di Estrazione* includes the same data as compiled in the *Lista di leva* and shown in Figure 1. The *liste di leva* are available for the classes (years of birth) 1870-1910 at the *Archivio di Stato di Nuoro* and for the classes 1911-1935 at the *Municipio di Villagrande*. The *Liste di Estrazione* were used for the classes 1853-1869 availaible at the *Archivio di Stato di Nuoro*.

2.3 Decision about conscript aptitude for military service

The decision taken by the *Consiglio di Leva* after the medical examination is reported as '*abile*' (fit), '*renitente*' (no appearence at the examination), '*rivedibile*' (temporaly unfit and reviewable next year) or '*riformato*' (definitely unfit). The decision *'renitente'* is taken when the conscript did not appear at the medical examination and the reason for it is specified: death, sickness with presentation of a medical certificate, *'detenuto'* if the boy is in prison, living in another village where he has been examined *'per delegazione'*, enroled in armed forces, *carabinieri* or other para-military forces including military administrative services, or *'disparuto'* (disappeared) if the boy was not found and is supposed to have emigrated outside the national territory. Along with the decision of *'riformato'* also its cause is reported, including values of height or chest circumference below the minimum requirement, or another obvious cause of unfitness.

3. Statistical analysis

Poor nutritional conditions may negatively affect the maximum genetically potential height that could not be attained at age 18. Thus the observed height and chest circumference at the time of the medical examination are adjusted by linear regression to estimate them exactly at 20^{th} birthday as done by other authors (Breschi et al., 2006; Fornasin et al. 2006).

Mean values and standard deviations are calculated for height and chest circumference both in the overall period and separately for three successive periods (1853-1892; 1893-1910; 1911-1935). The distribution of both variables is also checked for normality and skewness by means of the Kolmogorov-Smirnov test. The association between body parameters and demographic family characteristics is tested by one-way

analysis of variance. The existence of a possible decreasing log-linear gradient of parameters in relation to the size of the sibship is tested using a regression procedure. The variability of height and chest circumference within families is investigated by computing the standard deviation within family's compared to the overall standard deviation. In addition, mean quadratic differences of body parameters between conscripts belonging to the same sibship and conscripts randomly selected from different sibships have also been compared. All analyses were performed using Statistical Package for Social Science (SPSS, Chicago, Ill., USA) version 21. A significance level of $p<0.05$ was set for all calculations.

4. Results

4.1 Descriptive findings

In total we trace 1604 conscripts in the *Lista di Leva* and *Leva d'Estrazione* of the classes 1853 to 1935. Considering that numerous conscripts underwent more than one medical examination, the analysis considers the results of over 2000 examinations. Table 1 displays an overview of these medical evaluations and the decisions taken afterwards. The proportion of *riformati* as a final decision is nearly one third of the total number of conscripts of the classes 1853 to 1935 and for 73.7% of them the cause of unfitness was inability to meet the formal minimum body size requirements concerning height and chest circumference. However this proportion was not consistent throughout the three historical subperiods investigated. Among conscripts of the classes 1853 to 1892, 38.0% were declared unfit already at their first examination whereas 33.9% where declared as *abili* and only 28.1% were declared *rivedibili* and asked to be re-examined the subsequent year (Table 2). Conscripts born before 1893 were systematically declared as unfit if their height was below 154 cm, until 1871 and 153 cm, thereafter. The conscripts from subsequent classes underwent a more extensive recruitment forced by WWI and the need for larger numbers of soldiers. In 1917 the minimum requirement for height was lowered to 148 cm for *riformati* and 150 for *rivedibili* (Arcaleni, 1998). In this period the proportions of those declared *abili* and *rivedibili* at their first examination rose considerably, whereas the proportion of *riformati* was reduced by a factor of two. In subsequent years the criteria remained the same up to 1923 when the Italian act n°23 on 13 January in the *Gazzetta Ufficiale* decreed to revert to previous criteria. A new act n°1401 dated 26th September 1930 prescribed a minimum height for soldiers of 150 cm for *riformati* and 154 cm for *rivedibili* for the class 1911 examined in 1931 and the following ones. For conscripts born after 1910, the proportion of *riformati* decreased considerably and that resulted in increased proportion of *abili*.

In Villagrande information on height is available for 1387 conscripts out of 1489 (93%) at the time of their first examination. The information on height was not found for some years after 1932. Among the 102 conscripts without information on their height, 92

were declared *abili* and 10 were *riformati*, 4 were declared to be below the minimal height requirements. These numbers show a slightly higher proportion of *abili* among these 102 conscripts compared to all conscripts examined from 1933 to 1955 (85%), a small difference that could not influence the overall interpretation of our results. The frequency distribution of height among all conscripts at their first examination is displayed in Figure 2. This variable is almost normally distributed around the average height of 157.52 cm (Kolmogorov-Smirnov Z test of normality = 1.796, p = 0.003) with a slight negative asimmetry (-0.494) suggesting a relative excess of low values in the left tail. When considering the final decision of the *Consigli di Leva*, those declared *abili* (947 conscripts) had a mean height of 160.0 cm and those *riformati* (428 conscripts) only 153.7 cm with a mean height of 146.8 cm for the 313 conscripts declared to be *riformati per debolezza di costituzione*.

Chest circumference was reported only starting from the year 1887 for the class born in 1867. Values of the parameter have been found for 1135 conscripts out of 1489 (76% of all conscripts and 85% of those born in 1867 and later). Figure 3 shows the distribution of chest circumference which follows a normal curve around the average value of 81.9 cm (Kolmogorov-Smirnov Z tes of normality = 0.614, p = 0.838) with a weak negative asimmetry (-0.327) and a significant difference between those declared as *abile* or *riformato* in the final decision (83.3 vs 77.5 cm, p=0.003).

Concerning the reliability of these data, there was probably no possibility to measure height inaccurately considering the standard method used, wheras the accuracy of chest circumference is admittedly more questionable (Karpinos, 1961). This might account for the slight bi-modal distribution shown on Figure 3 as there was a minimum circumference fixed at 81 cm and the first peak is indeed at 80 cm just below the minimum required threshold.

As explained above, the mean age of conscripts at medical examination shows major variations during the period investigated owing to enrolment of younger conscripts during the two WWs (Figure 4). For this reason the measured body parameters are adjusted for unfinished growth when examined before age of 20 as suggested by Constanzo (1948) and done in most recent studies on Italian conscripts (Arcaleni et al. 2006; A'Hearn et al. 2009; Fornasin et al. 2006; Breschi et al. 2006). Therefore we use a linear regression to estimate the mean annual increase of the two anthropometric parameters and adjust the observed individual values by considering an increase of 1.0995 cm and 1.0925 cm per additional year of age, respectively for height and chest circumference.

The temporal evolution of the mean adjusted height observed at first medical examination of the conscripts of the classes 1853 to 1935 displays a steadily linear increase of about 0.05 cm increase per year (Figure 5). In contrast, the mean adjusted chest circumference show a non-linear evolution dependent on the period considered (Figure 6), namely a decrease for the classes born from 1867 to 1892 followed by an increase immediately thereafter for the classes of conscripts born from 1893 to 1910. For the

subsequent classes a stabilization of the mean chest circumference around 85 cm is observed. Considering this instable trend the period of observation has been subdivided in three sub-periods by considering separately the classes 1853-1892, 1893-1910 and 1911-1935.

5. Discussion

In this study we present an analysis of anthropometric data recorded on conscripts of Villagrande, a village where population show unique demographic characteristics (Poulain et al., 2011). Both height and chest circumference are investigated thus providing a double source of distinct and complementary information on body size and enabling a deeper insight on the population investigated. The data used concern 1,604 military conscripts of the classes 1853 to 1935. No particularly serious problems of sample representativeness emerges as during the historical period studied, military enlistment in Italy was universal. The exact age at examination is computed based on the precise dates of birth and medical examination and, considering that age, individual anthropometric parameters could be adjusted on the exact age of 20 years as previously proposed by several authors (Costanzo, 1948; Arcaleni et al. 2006; A'Hearn et al. 2009; Fornasin et al. 2006; Breschi et al. 2006).

The results of our analysis show that about 21 % of all conscripts of the classes 1853 to 1935 in Villagrande were declared *riformati* i.e. unfit for military service at the first examination, whereas about 30 % were eventually declared unfit in the final decision. In 3 out of 4 cases the reason for rejection was failure to achieve the minimum required height and/or chest circumference. This finding confirms historical reports stating that Sardinian conscripts showed the highest frequency of unfitness recorded within Italian regions (Livi-Bacci, 1986). Moreover, within the Sardinian population, it supports the fact that the Lanusei mountainous district experienced the worse situation (Villa Santa, 1914). Furthermore, a comparison with similar data collected in the population of Alghero for the corresponding classes born from 1866 to 1900 is illustrative of the specific situation of Villagrande (Cau et al. 2007). The percentage of conscripts from Villagrande declared as *abili* at the first examination is lower than that reported in the population of Alghero (33.8 vs 37.2, p=0.115), owing to a higher proportion of *riformati* (35.8 vs 31.8, p=0.068). The proportion of *rivedibili* was very similar (30.4 vs 31.0, p=0.779). This higher proportion of conscripts freed from military service in Villagrande shows a high degree of association with a smaller body size. The mean height of conscripts in Villagrande was remarkably lower and showed large variability compared with that reported by Cau et al. (2007) in Alghero (156.3 ± 7.9 cm vs 158.5 ± 4.8 cm, p <0.0001) and the same finding was detected also for chest circumference (80.0 ± 5.3 cm vs 82.1 ± 6.1 cm, p <0.0001). In general Sardinian conscripts as a whole show also lower values compared to Italy. In 1896 Livi reported an average height as low as 161.2 cm in Sardinian conscripts born in the period 1859-1863 in comparison with an average value of Italian ones of 164.5 cm. Conscripts born in the year 1874 were also the lowest in Italy (Costanzo, 1948), and the mean height of 163.3

cm of conscripts born in 1933 was still the second lowest in Italy compared to a national average of 167.5. Accordingly the magnitude of these anthropometric traits in Villagrande may be considered as remarkably low and that finding should deserve a specific attention from researchers.

The percentage of conscripts of Villagrande declared unfit is not consistent across the three historical subperiods investigated. In fact it is considerably lower for those born during the second subperiod (1893-1910) and even more during the third one (1911-1935). Several tentative explanations can be proposed for to this evidences, such as (i) the lowering of threshold from to 148 cm in 1917 urged by WWI needs, (ii) a possible less stringent tendency to declare a conscript unfit during the first period before the rise of conscriptions prompted by war, and (iii) the steady increase of mean body size of conscripts especially during the third subperiod.

Also the average value of both body parameters collected on Villagrande conscripts displays some evidence of variation over time. The increase of height over the period under study shows a slow linear temporal trend which has be documented also in other populations for the same period (Arcaleni, 2012; Danubio and Sanna, 2008; Larnkaer A, 2006). However we found that this average increase of height in Villagrande is slightly lower e.g. 0.05 cm per year compared with about 0.07 cm for Italy in the same period (Arcaleni 2012), and far more limited compared with the rise which has been observed for younger generations (Sanna, 2002). Besides, in a different Sardinian population (Alghero) the secular trend for the height was absent when comparing the conscripts of the classes 1886 to 1900 (Cau et al., 2007). A pivotal role of fertility decline has been suggested to explain up to 25% of the positive secular trend (Hatton and Martin, 2010). However this explanation would not be valid in the case of Villagrande where the decline in fertility had not yet started in the period considered and only a small number of conscripts born after 1930 are included in our analysis.

In constrast, mean chest circumference of conscripts exhibits a non-linear temporal trend. More precisely, conscripts born at the end of the 19th century show a relative decrease of the chest circumference, while those born at the turn of the 20th century display a surge, followed by a relatively stable plateau for classes born from 1911 on. In the absence of more precise evidence, the decrease of the mean chest circumference of conscripts born between 1893 and 1910 can only be addressed speculatively considering two hypothesis:

(i) A plausible systematic bias linked to the relative inaccuracy of the measurement of the chest circumference (Karpinos, 1961) that might also result in a greater variability. In addition, the desire to record lower values to get a fraudulent exemption from military service in an era characterized by a strong Italian war effort (Libya 1911, WWI) cannot be ruled out.

(ii) A significant degradation of living conditions during the last decade of the 19th century that lasted till the years following the WWI might be evoqued in connection with specific negative local events. Specifically, water shortage

devastated the rural population and caused thousands of cattle deads, the crisis in the mining sector determined by the closure of the Belgian market and the entrance of Italy into WWI may have caused nutritional insecurity, strong enough to determine significant impairment in anthropometric parameters of the population.

Compared with the temporal variation of height, the one of chest circumference seems to be more the result of changes in living conditions occurring in Sardinia at the turn of the 20th century. The increase of chest circumference in conscripts born after 1910, alongside the strong reduction of its overall variability, points to a significant improvement of nutritional status in the '20s, that could have been favoured by the efforts of post-war governments war to launch a policy of improvement of the general conditions of the population However the influence of specific confounding factors that were not taken into account in our analysis cannot be excluded.

References

1. A. Schumacher, "On the significance of stature in human society," Journal of Human Evolution, 11 (1982): 697–701.
2. A. Courtiol, M. Raymond, B Godelle and J.B. Ferdy. "Mate choice and human stature: homogamy as a unified framework for understanding mating preferences", Evolution 64 (2010): 2189–203.
3. T.T. Samaras, How height is related to our health and longevity: A review," Nutrition and Health 21 (2012): 247–61.
4. K. Silventoinen, "Determinants of variation in adult body height," Journal of Biosocial Science 35 (2003): 263–85.
5. K. Silventoinen, S. Sammalisto, M. Perola, D.I. Boomsma, B.K. Cornes, C. Davis, L. Dunkel, M. De Lange, J.R. Harris, J.V.B. Hjelmborg, et al. "Heritability of adult body height: a comparative study of twin cohorts in eight countries," Twin Res Hum Genet 6 (2003): 399–408.
6. A. Prentice, "The relative contribution of diet and genotype to bone development," Proc Nutr Soc 60 (2001): 45–52.
7. J. Baron, L. Sävendahl, F. De Luca, A. Dauber, M. Phillip, J.M. Wit, O. Nilsson. "Short and tall stature: a new paradigm emerges," Nat Rev Endocrinol (2015). doi: 10.1038/nrendo.2015.165.
8. C. Hancock, S. Bettiol, L. Smith "Socioeconomic variation in height: analysis of National Child Measurement Programme data for England," Arch Dis Child (2015) 308431. doi: 10.1136/archdischild-2015-308431.
9. J.M. Tanner, "Growth from birth to two: a critical review," Acta Med Auxol (Milano) 26 (1994): 7–45.
10. R. Livi, "Sulla statura degli italiani. Studio statistico antropologico," Archivio per l'antropologia e la etnologia 13 (1883):243-90, 317–79.
11. R. Livi, "Antropometria Militare," Roma: Tipografia E. Voghera, 1896 (parte I) and 1905 (parte II).
12. B.D. Karpinos, "Height and weight of youths of Selective Service registrants processed for military service during World War II," Human Biol 30, n. 4 (1958): 292–321.
13. B.D. Karpinos, "Current height and weight of youths of military age," Human Biol 33, n. 4 (1961): 335–54.
14. J. Komlos (ed.), "Stature, Living Standards, and Economic Development," Essays in Anthropometric History. Chicago: University of Chicago Press (1994).
15. M. Breschi, A. Fornasin and L. Quaranta, "La circonferenza toracica come indicatore dello stato nutrizionale e di salute (Friuli 1867-1910)," in: M. Breschi and L. Pozzi (eds.) Salute, Malattia e sopravvivenza in Italia fra '800 e '900, SiDES. Forum Editrice (2007). Udine. 157–74.
16. G.C. Alter and M. Oris, "Effects of Inheritance and Environment on the Heights of Brothers in Nineteenth-century Belgium," Human Nature 19, n. 1 (2008): 44–55.

17. S. Öberg, "Sibship size and height before, during, and after the fertility decline: A test of the resource dilution hypothesis," Demographic Research 32 (2015): 29-74; doi: 10.4054/Dem Res.2015.32.2.
18. J. Blake, "Family Size and the Quality of Children," Demography 18, n. 4 (1981): 421–42.
19. G.S. Becker, "A Treatise on the Family," Cambridge: Harvard University Press (1993).
20. V. Mazzarello, F.S. Carta, M.A. Sotgiu, P. Bandiera, "Paleoanthropological and Paleopathological study on human remains found in the Tombs I (Cell S) of S'Adde 'e Asile necropolis (Ossi - Sassari) ," IJAE 115 (2010), n. 1/2 (Supplement), 110.
21. M. Livi-Bacci, "Fertility, Nutrition, and Pellagra: Italy during the Vital Revolution," Journal of Interdisciplinary History 16, n. 3 (1986): 431–54.
22. Costanzo, "La statura degli italiani ventenni nati dal 1854 al 1920," Annali di Statistica 7, n. 2 (1948): 59-123.
23. M. Cappieri, "La statura degli italiani durante il secolo," Rivista di Antropologia 47 (1960): 295–300.
24. P. Grassivaro Gallo P, "L'evoluzione della statura in Italia. Analisi sui coscritti di leva tra il 1927 e il 1949," Genus 28 (1972): 171–203.
25. M. Zoledziewska, C. Sidore, C.W. Chiang, S. Sanna, A. Mulas, M. Steri, F. Busonero, J.H. Marcus, M. Marongiu, A. Maschio, D.O. Del Vecchyo, M. Floris, A. Meloni, A. Delitala, M.P. Concas, F. Murgia, G. Biino, S. Vaccargiu, R. Nagaraja, K.E. Lohmueller; UK10K Consortium, J.N. Timpson, N. Soranzo, I. Tachmazidou, G. Dedoussis, E. Zeggini; Understanding Society Scientific Group, S. Uzzau, C. Jones, R. Lyons, A. Angius, G.R. Abecasis, J. Novembre, D. Schlessinger, F. Cucca, "Height-reducing variants and selection for short stature in Sardinia," Nat Genet 47, n. 11 (2015): 1352–6.
26. J.B. Foster, "The evolution of mammals on islands," Nature 202, n. 4929 (1964): 234–5.
27. Centro Studi Confindustria, "Indicatori economici provinciali," Rosa G. e Esposto M. Eds. Roma: SIPI (1989).
28. ISTAT, "Sommario storico di statistiche sulla popolazione. Anni 1951-1987," Istituto Nazionale di Statistica, Roma (1990).
29. E. Sanna, "Il secular trend in Italia," Antropo 3 (2002): 23–49.
30. P. Grasgruber, J. Cacek, T. Kalina, M. Sebera, "The role of nutrition and genetics as key determinants of the positive height trend," Econ Hum Biol 15 (2014): 81–100.
31. K. Silventoinen, J. Kaprio, L. Dunkel, Y. Yokoyama, "Genetic and environmental influences on chest circumference during infancy: a longitudinal study of Japanese twins," Paediatr Perinat Epidemiol 26 (2012): 553–60.
32. S. Chatterjee, N. Das, P. Chatterjee, "The estimation of the heritability of anthropometric measurements," Applied Human Science 18 (1999): 1–7.

33. M. Poulain, G.M. Pes, L. Salaris "A population where men live as long as women: Villagrande Strisaili, Sardinia," J Aging Res (2011): 153756.
34. G.M. Pes, F. Tolu, M. Poulain, A. Errigo, S. Masala, A. Pietrobelli, N.C. Battistini and M. Maioli, "Lifestyle and nutrition related to male longevity in Sardinia: an ecological study," Nutr Metab Cardiovasc Dis 23 (2013): 212–19.
35. M. Poulain, G.M. Pes, C. Grasland, C. Carru, L. Ferrucci, G. Baggio et al., "Identification of a geographic area characterized by extreme longevity in the Sardinia island: the AKEA study," Exp Gerontol 39 (2004): 1423–9.
36. C. Lamioni, "Gli Uffici di leva dall'Unità d'Italia. Le istituzioni e la documentazione all'Archivio di Stat di Firenze," Population e Storia, SiDES 2 (2002): 127–53.
37. M. Breschi, A. Fornasin and L. Quaranta, "Heights of twenty years old males of Friuli (Italy) born between 1846 and 1890," Statistica 66, n. 4 (2006): 390–413.
38. A. Fornasin and L. Quaranta, "La statura degli italiani nati dal 1854 al 1890. Prime ipotesi per la construzione di una nuova serie storica," Working Paper n°8. Dipartimento di Scienze Statistiche dell' Universita di Udine, (2006), 20 pp.
39. E. Arcaleni, "La statura dei coscritti italiani delle generazioni 1854-1976," Bolletino di Demografia Storica 29 (1998) : 23–59.
40. E.Arcaleni, "Secular trend and regional differences in the stature of Italians," J.Anthropol Sci 90 (2012): 233–7.
41. M. Breschi, A. Fornasin and L. Quaranta, "La circonferenza toracica come indicatore dello stato nutrizionale e di salute (Friuli 1867-1910) ," in Breschi M. and L. Pozzi (eds.) Salute, Malattia esopravvivenza in Italia fra '800 e '900, SiDES. Forum Editrice. Udine (2007): 157-74.
42. E. Arcaleni, "Secular Trend and Regional Difference in the Stature of Italians, 1854-1980". Economics and Human Biology (2006) 44:24-38.
43. B. A'Hearn, F. Peracchi, and G. Vecchi. "Height and the Normal Distribution: Evidence from Italian Military Data". Demography (2009) 46(1): 1-25.
44. N. Villa Santa, "Le condizioni economiche di un circondario della Sardegna (Lanusei)," Olivero e C., Torino, 1914.
45. P. Cau, C. Merella and L. Pozzi, "Lo stato di salute della popolazione di Alghero fra '800 e '900," In: M. Breschi and L. Pozzi (eds.) Salute, Malattia esopravvivenza in Italia fra '800 e '900, SiDES. Forum Editrice. Udine, (2007) 135–156.
46. M.E. Danubio, E. Sanna, "Secular changes in human biological variables in Western countries: an updated review and synthesis," J Anthropol Sci 86 (2008): 91–112.
47. A. Larnkaer, S. Attrup Schrøder, I.M. Schmidt, M. HørbyJørgensen, K. Fleischer Michaelsen, "Secular change in adult stature has come to a halt in northern Europe and Italy," Acta Paediatr 95 (2006): 754–5.

Figure 1. Example of information included for each conscript in the Lista di Leva and Lista di Estrazione (Municipio of Villagrande).

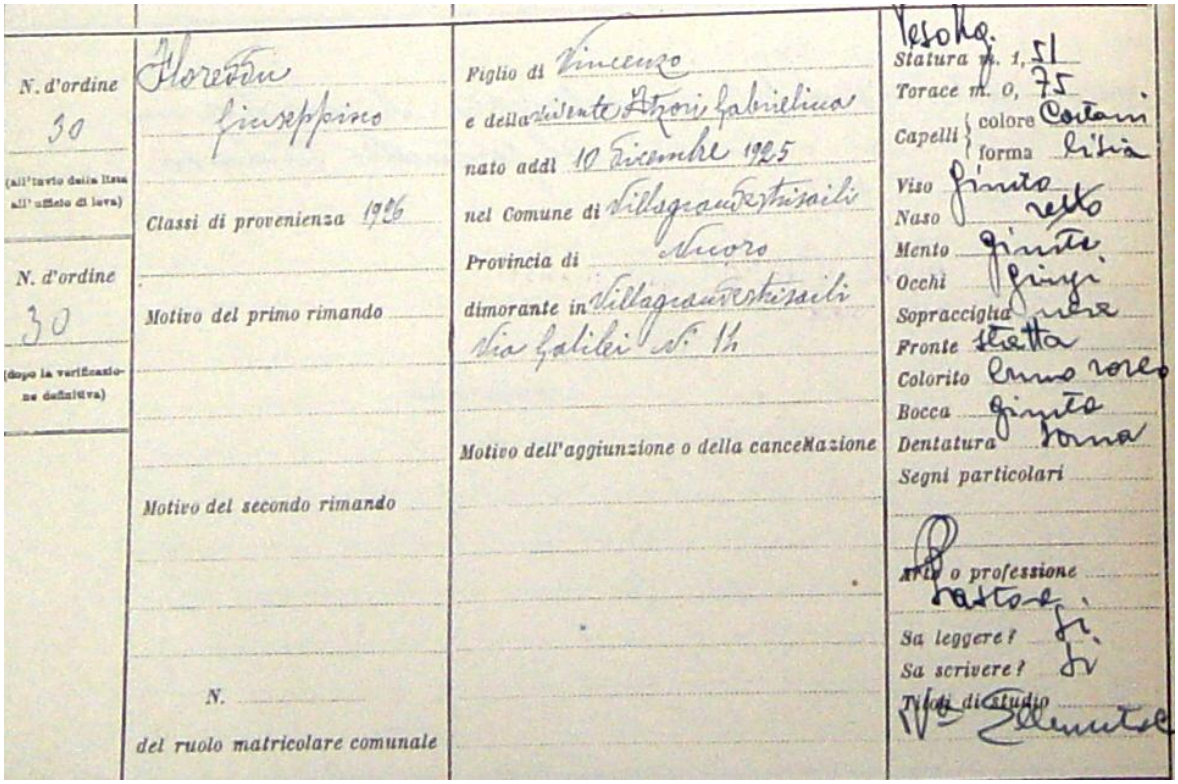

Figure 2. Distribution of height of the 1387 conscripts with information available at their first medical examination.

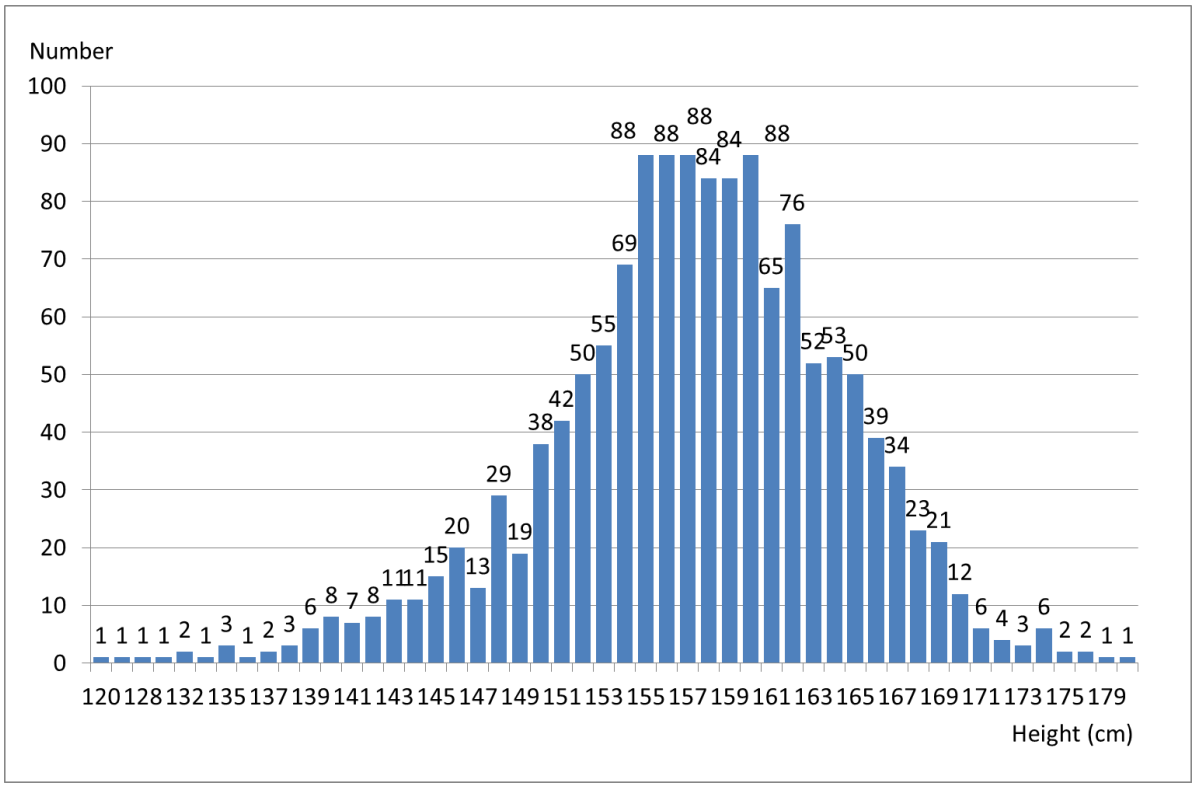

Figure 3. Distribution of chest circumference of the 1184 conscripts with information available at their first examination.

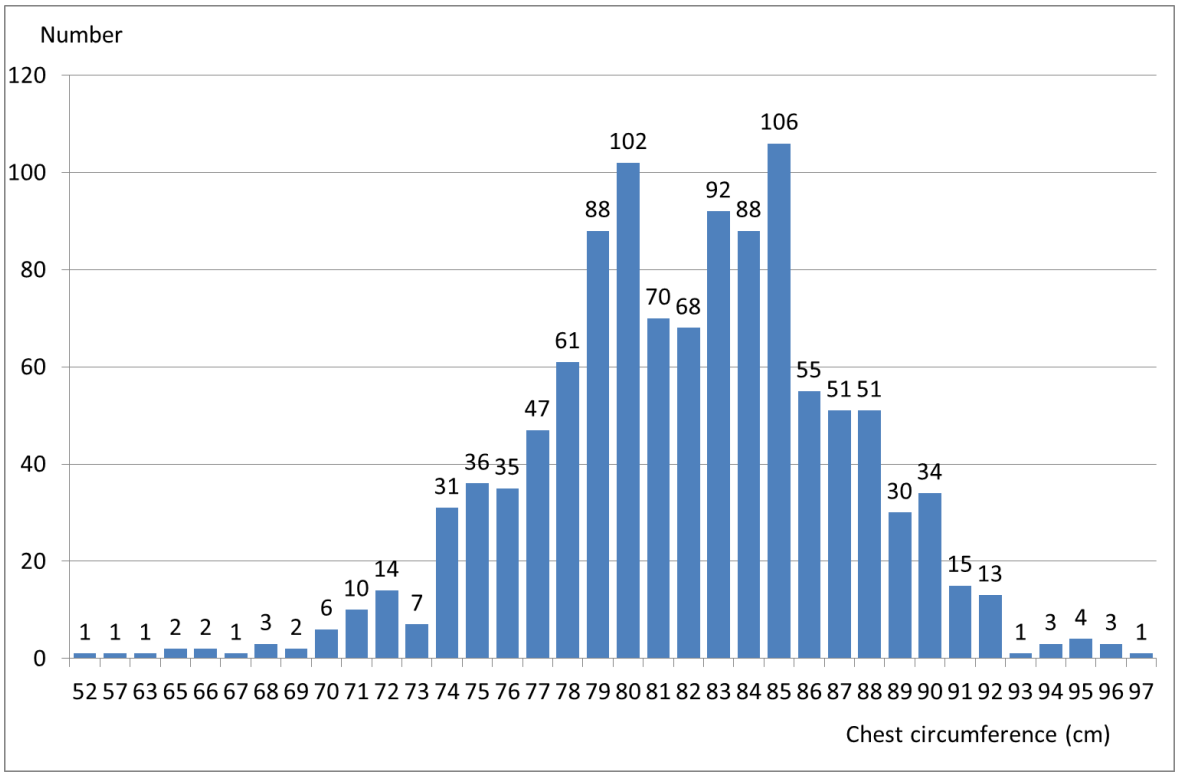

Figure 4. Mean age at the first medical examination by year of examination (1873-1955)

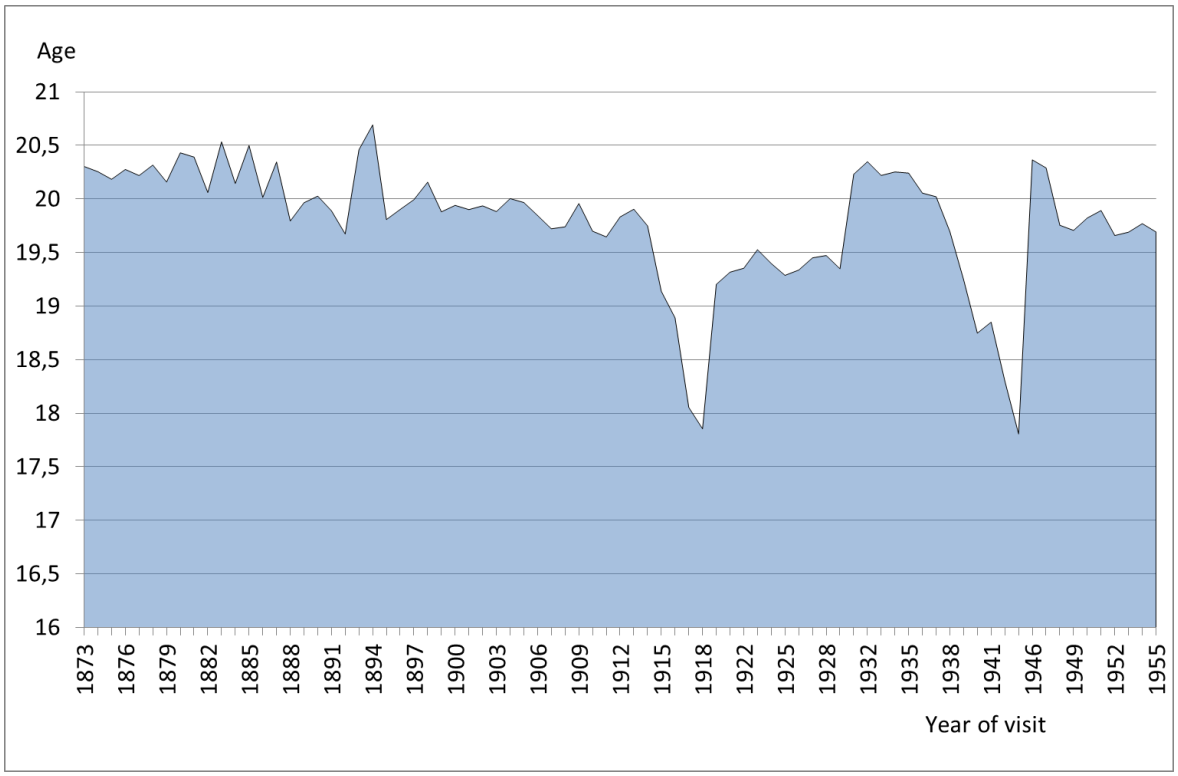

Figure 5. Mean adjusted height at the first medical examination by class of conscripts (year of birth 1853-1935)

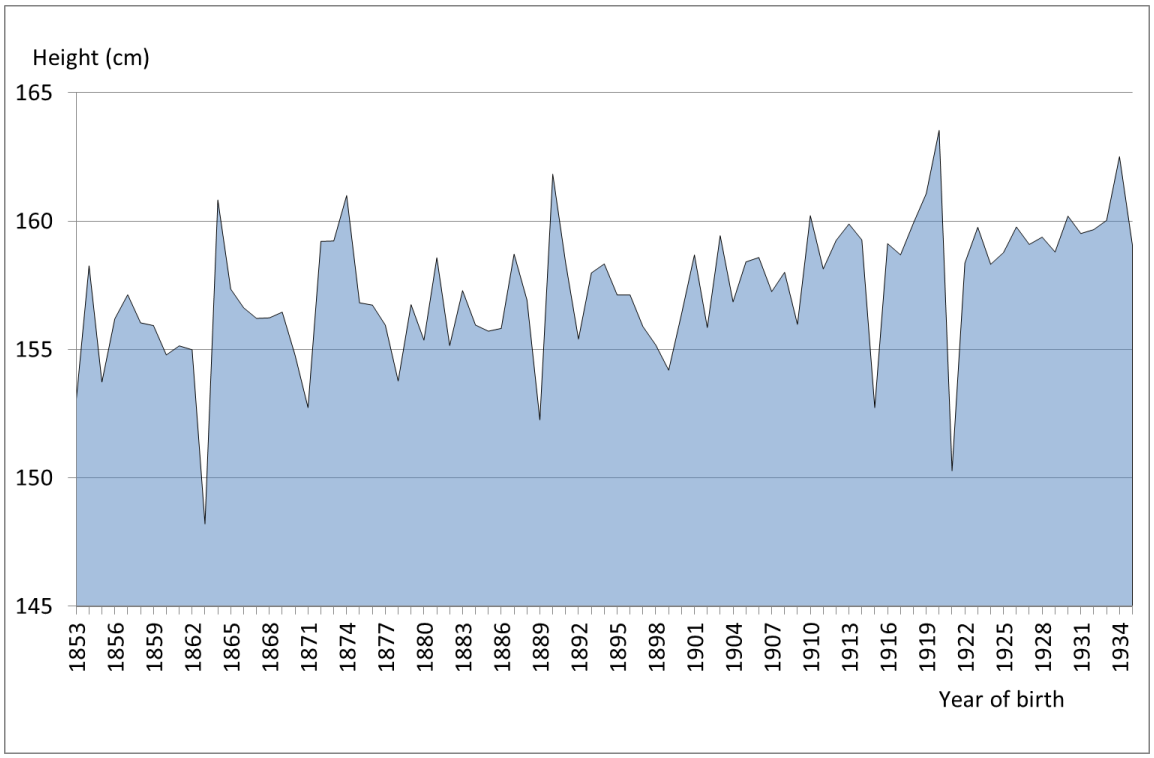

Figure 6. Mean adjusted chest circumference at the first medical examination by class of conscripts (year of birth 1853-1935)

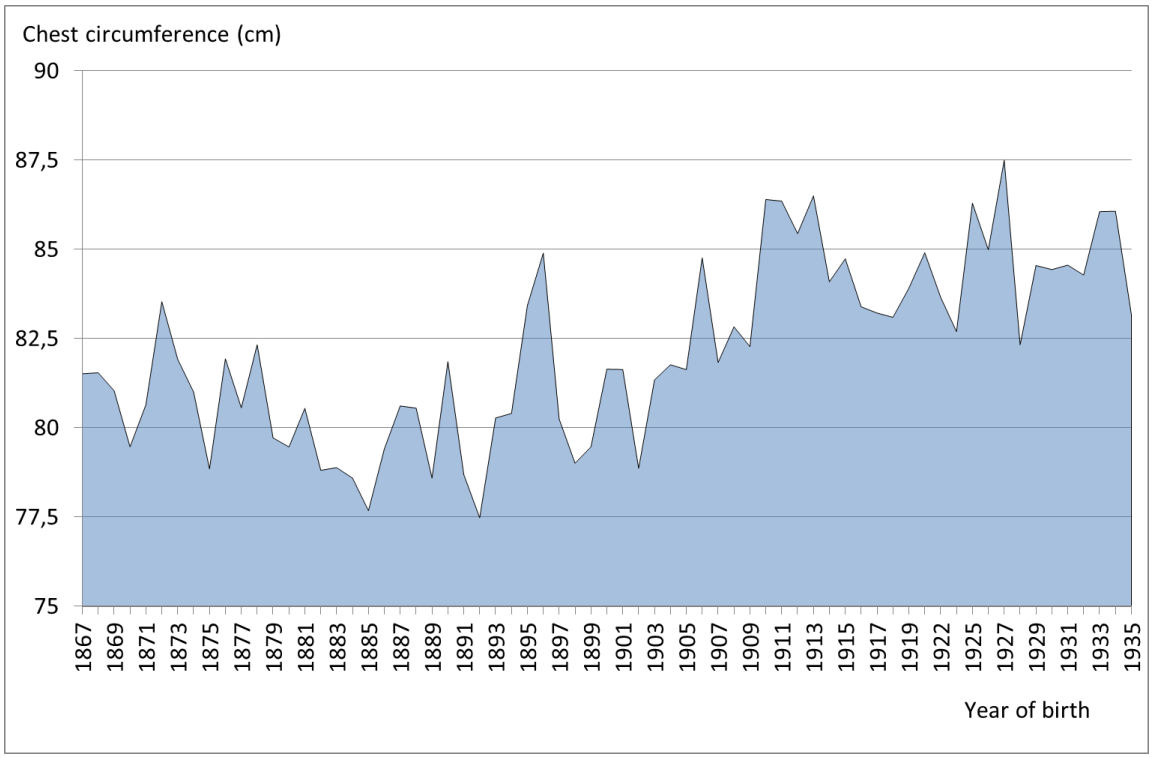
Chest circumference (cm)
90
87,5
85
82,5
80
77,5
75
1867
1869
1871
1873
1875
1877
1879
1881
1883
1885
1887
1889
1891
1893
1895
1897
1899
1901
1903
1905
1907
1909
1911
1913
1915
1917
1919
1922
1925
1927
1929
1931
1933
1935
Year of birth

Table 1. Summary of the military examinations for the 1604 boys born in Villagrande between 1853 and 1935 and alive at age 18.

Total number of conscripts born in the years 1853 – 1935	**1604**
Renitenti (failed to report for service)	76 (4.7%)
Of whom engaged in army or other paramilitary forces as *carabinieri*	39 (2.4%)
Did the first medical visit	**1489**
Abili (fit)	758 (50.9%)
Riformati (definitely unfit)	316 (21.2%)
Of which for default of height or chest circumference	243 (16.3%)
***Rivedibili* (suitable for a second examination)**	**415**
Renitenti (failed to report for service)	9 (2.2%)
Abili (fit)	168 (40.5%)
Riformati (definitely unfit)	47 (11.3%)
Of whom for height or chest circumference below the minimum required	17 (4.1%)
***Rivedibili* (suitable for a third examination)**	**191**
Renitenti (failed to report for service)	3 (1.6%)
Abili (fit)	102 (53.4%)
Riformati (definitely unfit)	69 (36.1%)
Of whom for height or chest circumference below the minimum required	52 (27.2%)
***Rivedibili* (suitable for a fourth examination)**	**17**
Renitenti (failed to report for service)	0 (0.0%)
Abili (fit)	11 (64.7%)
Riformati (definitely unfit)	6 (35.3%)
Of whom for height or chest circumference below the minimum required	5 (29.4%)

Total number of '*abili*'	1039 (69.8%)
Total number of '*riformati*'	438 (29.4%)
Of whom for height or chest circumference below the minimum required	317 (72.1%)
Conscripts who had disappeared between two successive examinations	12 (0.8%)

Table 2. Decisions taken by the Consiglio di Leva after the first examination and final decision by group of classes of conscripts

	1853-1892	1893-1910	1911-1935	TOTAL
Number of conscripts	516	363	508	1387
Decision after the first examination				
Abili	175 (33.9%)	153 (43.1%)	353 (69.5%)	681 (49.1%)
Riformato	196 (38.0%)	63 (17.3%)	47 (9.2%)	306 (22.1%)
Rivedibili	145 (28.1%)	147 (40.6%)	108 (21.3%)	400 (28.8%)
Final decision				
Abili	268 (51.9%)	265 (73.0%)	432 (85.0%)	965 (69.6%)
Riformato	248 (48.1%)	98(27.0%)	76 (15.0%)	422 (30.4%)
of whom for stature deficiency	*214 (86.3% of 248)*	*62 (63.3% oF 98)*	*35 (46.1% of 76)*	*311 (73.7% of 422)*