DEMOGRAPHIC RESEARCH

Descriptive Finding

Demographic characteristics of Sardinian centenarian genealogies: Preliminary results of the AKeA2 study

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Abstract

OBJECTIVE

This article provides an overview of the AKeA2 study, with a particular focus on data collection concerning family genealogies of the Sardinian centenarians and controls, and on the quality of these data. A first analysis of the main characteristics of the survey data is also summarized and selected preliminary results are presented.

METHODS

We use descriptive statistics to analyze data collected by the AKeA2 survey on Sardinian centenarians and controls.

RESULTS

Centenarian women have on average fewer children, and at an older age, particularly for their last child. The mothers of centenarians, especially centenarian women, lived longer on average than those of deceased controls and controls born between 1905 and 1910 but still living at the moment of the survey.

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1. Introduction

In Sardinia, male death rates after age 80 are only modestly higher than female death rates, and are lower than female levels in some municipalities. The remarkably low mortality after age 80 has thus yielded a surprisingly large number of centenarian men compared with centenarian women (Robine and Caselli 2005). An area with a large number of centenarians has been identified in the Sardinian province of Nuoro (Deiana et al. 1999; Poulain et al. 2004), as well as a longevity area for men. This latter area comprises municipalities in Oristano as well as Nuoro where the standardized death rate across old ages for men is less than 10% higher than for women, whereas elsewhere in the two provinces the standardized male death rate is more than 30% higher (Caselli and Lipsi 2006). The higher number of centenarians and their more balanced sex ratio have led to considerable interest among demographers, geneticists, gerontologists, and clinicians specializing in genetic mapping (DNA) (Caselli, Robine, and Rasulo 2003).

The bio-medical characteristics of Sardinian centenarians was investigated by Luca Deiana and Giovannella Baggio (Deiana et al. 1999) in the AKeA study, an acronym derived from an expression in the Sardinian dialect that means "may you live to 100." A second, larger and cross-disciplinary study, called AKeA2, was launched in 2003, which involved demographers, historians, biologists, geneticists, and gerontologists. The demographic survey was directed by James Vaupel.

This article gives a short description of the AKeA2 demographic survey and of the data collection, and provides a preliminary analysis of the data.

2. Overview of the AKeA2 study: Sample selection and data collection plan

The data collection was time-consuming. Over a six-year period various types of information were gathered: individual demographic characteristics, data on survival rates, and archival data regarding family characteristics and early-life events.

The AKeA2 demographic survey was planned to involve Sardinian centenarians (100 men and 100 women) and their controls, by differentiating between living and deceased controls. All the controls were of the same sex as the centenarian, born and still resident in the same place of birth, and their day and month of birth were as close as possible to that of the centenarian. Picking the person with the most similar day and month of birth is a convenient method of selecting a matched individual, and this strategy controls for season-of-birth effects, which are known to affect longevity (Doblhammer 1999; Doblhammer and Vaupel 2001; Gavrilov and Gavrilova 1999).

As concerns the living controls, the plan was to identify three younger controls for each centenarian by finding people born around 1907, 1912, and 1922. We also identified, for each centenarian, two deceased controls that were born, as mentioned before, the same year (and around the same day and month) and in the same municipality as the centenarian and to find one who died in his or her late 60s and one who died in his or her late 70s.

In choosing both controls it was required that the family names of their mothers and fathers had to be different from the family names of the centenarian's parents. Controls with a familial relationship with centenarians were excluded from the sample, to avoid possible excessive consanguinity. Satisfying all these requirements was not always possible, but as shown in Table 1 we succeeded in locating appropriate controls for most of the centenarians.

We succeeded in collecting information on 204 centenarians, 98 males and 106 females. These people were born between 1890 and 1904, in 126 municipalities (Figure 1) throughout the island (out of the 377 Sardinian municipalities). Table 1 shows 54 out of 98 centenarian men were from the provinces of Nuoro and Oristano, the provinces that included the longevity areas with exceptionally low male mortality.

Regarding the living controls, in small municipalities individuals born in 1907, 1912, and 1922 could not always be located. Hence, individuals from adjacent cohorts were identified, specifically born between 1905 and 1910, 1911 and 1917, and 1918 and 1923.

Prior to being interviewed, the centenarian's willingness to be visited was established by first contacting their general practitioner and/or family, who were asked to participate in the survey. If they refused the centenarian was replaced with a similar substitute, where possible.

We had hoped to find two deceased controls for each centenarian, but fell somewhat short, because in some of the smaller municipalities appropriate people could not be identified.

Table 1:   **Individuals in the survey by birth cohort, sex, province, and region**

Year of Birth	Men					Women					M+W
	Cagliari	Nuoro	Oristano	Sassari	Sardinia M	Cagliari	Nuoro	Oristano	Sassari	Sardinia W	Sardinia
Centenarians											
1890-1892	0	1	0	0	1	0	0	0	0	0	1
1893-1895	0	1	0	0	1	0	2	0	0	2	3
1896-1899	1	6	0	4	11	1	7	2	4	14	25
1900	2	2	0	0	4	1	4	2	5	12	16
1901	1	3	1	2	7	1	11	5	16	33	40
1902	7	10	3	10	30	4	9	6	12	31	61
1903	4	11	5	3	23	1	5	3	5	14	37
1904	5	9	2	5	21	0	0	0	0	0	21
Total	20	43	11	24	98	8	38	18	42	106	204
Living controls											
1905-1910	15	38	8	20	81	7	35	16	37	95	176
1911-1917	20	43	10	24	97	8	38	18	42	106	203
1918-1923	20	43	11	23	97	8	38	18	41	105	202
Total	55	124	29	67	275	23	111	52	120	306	581
Deceased controls aged 60-69 years											
1890-1892	0	1	0	0	1	0	0	0	0	0	1
1893-1895	0	1	0	0	1	0	2	0	0	2	3
1896-1899	1	6	0	3	10	1	5	1	3	10	20
1900	1	2	0	0	3	1	3	0	4	8	11
1901	0	3	1	2	6	1	10	5	13	29	35
1902	7	8	2	8	25	3	9	4	10	26	51
1903	3	11	3	3	20	0	5	3	3	11	31
1904	2	9	2	5	18	0	0	0	0	0	18
Total	14	41	8	21	84	6	34	13	33	86	170
Deceased controls aged 70-79 years											
1893-1895	0	1	0	0	1	0	2	0	0	2	3
1896-1899	1	6	0	3	10	1	6	1	4	12	22
1900	2	2	0	0	4	1	3	2	5	11	15
1901	1	3	1	2	7	1	11	4	12	28	35
1902	6	10	3	10	29	4	8	6	11	29	58
1903	4	11	4	4	23	1	5	4	4	14	37
1904	5	8	2	5	20	0	0	0	0	0	20
Total	19	41	10	24	94	8	35	17	36	96	190

In total, 1,145 individuals were included in the survey: 204 centenarians, 581 living controls, and 360 deceased controls. A code was assigned to each individual to allow linkage between the questionnaire data and bio-medical information, and data from the civil records. The 1,145 individuals (living and deceased) included in the survey were validated on the basis of two types of population register.

Figure 1:   Distribution of centenarians in the 126 Sardinian municipalities
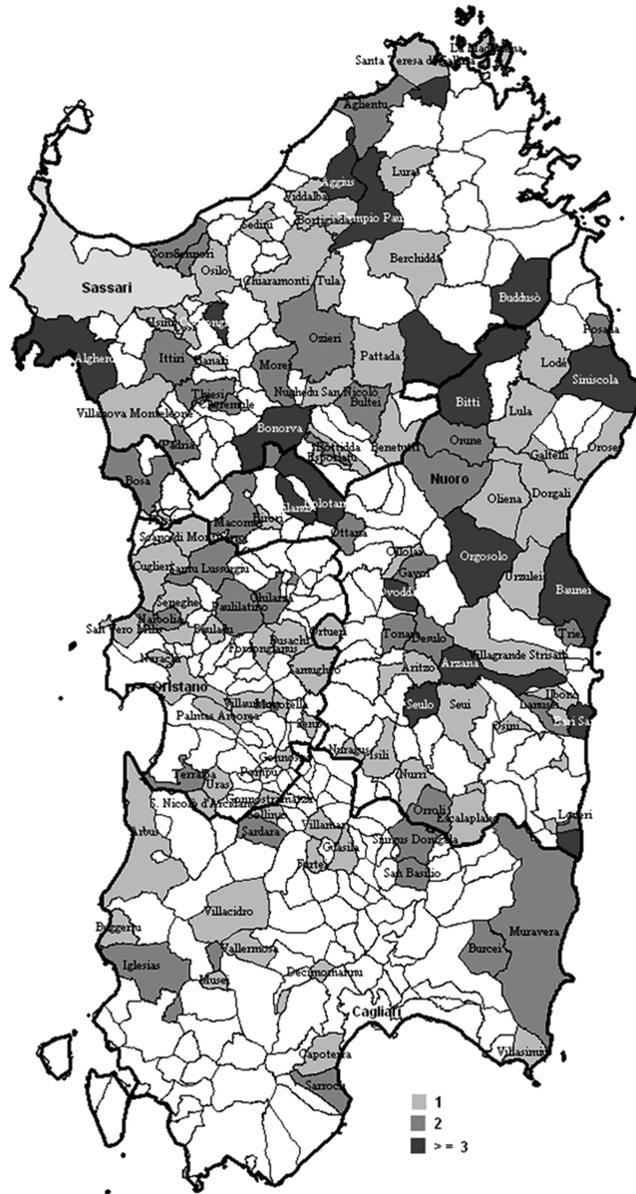
3. Validation procedure

Sardinian municipalities, as elsewhere throughout Italy, have two types of population register. One collects civil records, recording births, deaths, and marriages that occur in the municipality in question. Sardinian civil records have been collected since 1866. The second – the *Anagrafe* – records residence and change of residence as well as residents' births, deaths, and marriages.

To validate ages in our study, the following documents were examined: birth certificate, marriage certificate(s), the birth, marriage, and death certificates of parents, the birth certificates of all children of the individual in question, and the birth certificates of the individual's siblings. Complete validation is achieved only when the data is cross-checked and proves to be consistent.

Firstly, the consistency of the data was checked by verifying that birth and death registers were in agreement if the individual had died, or that the birth register and the *Anagrafe* were in agreement if he or she was living (date and place of birth, names given to the new-born, names of parents, age of father if given).

Secondly, we checked the coherence between names given in the various records. Then we verified the consistency of the marriage register regarding parents' marriage (name of spouses, date and place of marriage, ages), checking the plausibility of the age at marriage of both spouses. Next we checked the plausibility of all between-birth intervals for the individual and siblings, taking into account those who died in their first year of life. A repetition of the name given to siblings often can be explained by the death of a former sibling; this must be considered for age validation.

The validation process was quite lengthy. Over two and a half years passed between the date of interview and the time it took to collect all the data for both centenarians and controls. During this period a number of deaths occurred and were duly entered in the death register.

4. Completeness of the information

By applying the validation procedure to demographic data from 1866, genealogies were reconstructed for 1,145 individuals. Specifically, for each individual we have reconstructed his/her life history as well as the biographies of his/her ancestors and descendants. These were then uploaded using "Heredis 8" (2007) (a software for reconstructing genealogies), to compile a database of 21,788 individuals, including the ascendants, siblings, and descendants of the sampled subjects.

The analysis of missing data highlighted that full information (100%) is available for all sampled individuals regarding year and place of birth, date and place of death (if

deceased); data on second marriages; the number and sex of their children. Widow status is also recorded, but is missing for 18% of men and 23% of centenarian women (Table 2).

Information on the parents concerning date and place of birth is available for all sampled individuals. Other information is available for many of them, such as date of death (92% of centenarians), marriage (from 94 to 98%), and fertility (from 94 to 99%).

Table 2: **Synthesis of some demographic characteristics concerning centenarians and controls. Values per 100**

Demographic characteristics	Individuals in the survey						
	Centenarians	Living controls			Deceased controls		Total Individuals
		1905 – 1910	1911 – 1917	1918 – 1923	Aged 60–69 years	Aged 70–79 years	
Men							
Number of individuals	98	81	97	97	84	94	551
Deceased at the moment of the civil register checks	48.0	30.9	16.5	8.2	100.0	100.0	49.7
Place of death different from place of birth	19.1	32.0	12.5	75.0	4.8	4.3	12
No information on vital status	6.1	2.5	2.1	2.1	0	0	2.2
Emigrated at the moment of the demographic checks	4.1	1.2	1.0	0	0	0	1.1
Never married (1)	8.2	7.4	4.1	12.4	13.1	3.2	8.0
Second marriages	8.9	5.3	6.5	0	6.8	9.9	6.3
Married at the moment of the civil register checks	7.8	33.3	45.2	80.0	78.1	58.2	49.7
Widows at the moment of the civil register checks	74.4	62.7	50.5	11.8	17.8	41.8	43.8
No information on civil status at the moment of the civil register checks	17.8	4.0	4.3	8.2	4.1	0	6.5
Women							
Number of individuals	106	95	106	105	86	96	594
Deceased at the moment of the civil register checks	54.7	33.7	20.8	6.7	100.0	100.0	50.7
Place of death different from place of birth	27.6	15.6	9.1	28.6	1.2	4.2	10.0
No information on vital status	5.7	2.1	5.7	1.0	0	0	5.7
Emigrated at the moment of the demographic checks	4.7	1.1	2.8	1.9	0	1.0	2.0
Never married (1)	19.8	26.3	11.3	20.0	22.1	20.8	19.9
Second marriages	2.4	2.9	3.2	3.6	1.5	2.6	2.7
Married at the moment of the civil register checks	0	2.9	6.4	25	58.2	21.1	17.6
Widows at the moment of the civil register checks	76.5	87.1	85.1	72.6	38.8	72.4	73.1
No information on civil status at the moment of the civil register checks	23.5	10.0	8.5	2.4	3.0	6.6	9.2

The differences between centenarians and controls are significant at the level of α<0.05 (Student's t-test).
(1) The proportion of married individuals (first marriage) is the complement to 100.

5. Some preliminary results

A first result regards the average age at death: for centenarians it was 102.4 years and 102.2 respectively for women and men (Table 3). Differences between the sexes also emerged for controls for the 1905–1910 and 1911–1917 cohorts, where the mean age at death was 96.8 and 91.9 for women and 96.5 and 90.3 for men, respectively. Surprisingly, for deceased controls who died in their late 60s, the mean age at death was significantly lower for women (67.1 years) than for men (68.0 years).

Only 16 participants (6 men and 10 women) changed their residence, but any migration that took place was limited to within the island.

Regarding fertility, especially for the mean number of children per woman, there are significant differences between centenarians and their deceased control and living controls for the 1905–1910 cohorts. Table 3 shows that centenarian women (excluding childless women - we restricted the analysis to women that had experienced a 'birth event') had an average of 5.4 children compared with 5.6 children for women in the same cohorts deceased at ages 60–69 and 5.8 children for women in the 1905–1910 cohorts. No comparison can be made with younger cohorts, that is to say, women in the 1918–1923 cohort. The reproductive age of these cohorts mostly coincides with the second demographic transition in Italy when there was a fertility decline, so that they experienced the first major drop in fertility.

In the case of centenarian women the mean age at birth for total fertility was almost 33 years (Table 3), higher than that of the deceased controls (31−32 years). The mean age at first child is also higher (26.7 years), especially when compared to women belonging to the same cohorts who died at 70−79 years (26.2 years). It is worth stressing that the centenarian women also have a mean age at last birth higher than that of the deceased controls, suggesting that their biological fertility period may extend to later ages.

Table 3: **Some demographic indicators concerning civil status, fertility, and infant mortality for centenarians and controls**

Demographic indicators	Individuals of the survey					
	Centenarians	Living controls			Deceased controls	
		1905 – 1910	1911 – 1917	1918 – 1923	Aged 60–69 years	Aged 70–79 years
Men						
Mean age at 1st marriage	31.8	30.7	30.6	32.5	30.4	30.3
Mean age of their spouses at 1st marriage	26.0	24.7	24.9	26.9	25.5	24.9
Never married (per 100)	8.2	7.4	4.1	12.4	13.1	3.2
Childless (per 100)	17.3	9.9	13.4	18.6	20.2	9.6
Mean number of children out of all individuals	4.5	4.9	4.4	3.2	4.4	5.3
Mean number of children **excluding** individuals without children	5.4	5.4	5.1	4.0	5.6	5.9
Mean age at birth	38.1	37.5	37.4	36.6	37.6	37.2
Mean age at the first birth	32.3	31.3	31.6	33.2	31.7	30.5
Mean age at the last birth	44.3	43.1	43.3	41.8	44.4	44.2
Death of children aged 0-1 years out of total births (per 1000)	96.2	82.0	95.8	60.4	100.0	102.3
Father's mean age at the birth of the dead child	36.9	34.5	33.6	33.9	36.9	34.8
Mean age at death at the moment of the civil register checks	102.2	96.5	90.3	82.1	68.0	77.1
Women						
Mean age at 1st marriage	26.9	27.4	26.8	25.0	26.4	27.7
Mean age of their spouses at 1st marriage	33.5	32.6	31.9	31.7	32.9	35.6
Never married (per 100)	19.8	26.3	11.3	20.0	22.1	20.8
Childless (per 100)	28.3	34.7	20.8	26.7	27.9	34.4
Mean number of children out of all individuals	3.9	3.8	3.7	3.7	4.1	3.3
Mean number of children **excluding** individuals without children	5.4	5.8	4.7	5.1	5.6	5.1
Mean age at birth	32.7	31.8	32.0	31.0	32.1	31.2
Mean age at the first birth	26.7	26.7	27.0	25.5	26.6*	26.2
Mean age at the last birth	38.5	39.2	37.7	37.7	38.0	37.8
Death of children aged 0-1 years out of total births (per 1000)	78.9	117.2	111.8	74.2	118.1	171.5
Mother's mean age at the birth of the dead child	34.7	31.5	31.0	30.4	32.5	30.8
Mean age at death at the moment of the civil register checks	102.4	96.8	91.9	82.4	67.1	77.4

The differences between centenarians and controls are significant at a level of α<0.05 (Student's t-test)
* The difference with centenarians is not significant

Table 4 shows the fertility of the surveyed individuals' parents. Mothers of both centenarian men and women had a higher number of children on average than mothers of the deceased controls of centenarian women. Furthermore, their mothers' mean age at their birth is 30.6 years, which is lower than that of less long-lived people: 32.0 years for those who died in their 60s and 31.7 years for those who died in their 70s. Similarly, the father's mean age at their birth is 37.5 years compared with 39.4 and 38.0 for the two deceased groups.

Table 4: **Some demographic indicators concerning fertility and mortality of the parents of centenarians and controls**

Demographic indicators	Individuals of the survey					
	Centenarians	Living controls			Deceased controls	
		1905 – 1910	1911 – 1917	1918 – 1923	Aged 60–69 years	Aged 70–79 years
	Men					
Mean number of children for mother	6.3	6.6	6.2	6.4	6.2	5.9
Mean number of children for father	6.1	6.7	6.4	6.5	6.3	5.9
Mother's mean age at birth for each of these individuals	30.1	31.2	31.3	31.6	30.7	31.0
Father's mean age at birth for each of these individuals	36.7	38.6	38.9	38.8	36.6	38.4
Birth order of each individual of the survey	3.1	3.4	3.8	3.2	3.4	3.2
Mother's mean age at death	71.3	71.4	71.1	76.9	71.2	70.0
Father's mean age at death	70.1	74.5	75.0	77.2	70.7	69.9
	Women					
Mean number of children for mother	6.9	6.9	6.7	6.2	6.3	6.6
Mean number of children for father	6.8	6.9	6.7	6.2	6.3	6.6
Mother's mean age at birth for each of these individuals	30.6	30.9	31.7	30.4	32	31.7
Father's mean age at birth for each of these individuals	37.5	37.5	37.8	36.5	39.4	38.0
Birth order of each individual of the survey	3.8	3.6	3.7	2.9	3.8	3.7
Mother's mean age at death	74.1	70.9	74.3	77.9	68.7	70.6
Father's mean age at death	71.3	73.5	71.8	75.3	68.3	72.2

The differences between centenarians and controls are significant at a level of α<0.05 (Student's t-test)

Birth order for centenarian men and women is also of some interest, both in the light of the existing literature (Doblhammer 2000; Voland and Engel 1986; Westendorp and Kirkwood 1998) and, above all, in relation to the results obtained in other studies on late reproduction, parity, and longevity in Sardinian women (Astolfi et al. 2009). On average the birth order is 3.1 for men and 3.8 for women (Table 4). For centenarian men the birth order is lower compared with their deceased controls, particularly for those who died in their 60s.

Another interesting result concerns parents' age at death. Mothers of centenarians, especially of centenarian women, lived longer on average (74.1 years) than the mothers of deceased controls and living controls born in 1905–1910 (70.9 years) (Table 4). We regard this result as very important, particularly in relation to the many results recently obtained in genetics. All the data collected in this and other studies suggest that, as well as a variety of nuclear DNA polymorphisms (Di Bona et al. 2009; Gravina et al. 2009; Invidia et al. 2010; Lescai et al. 2009; Lescai, Marchegiani, and Franceschi 2009; Salvioli et al. 2006; Testa et al. 2009), maternally inherited mitochondrial DNA variants (Capri et al. 2008; Raule et al. 2007; Rose et al. 2007; Rose et al. 2010; Santoro et al. 2006) contribute substantially to human longevity too.

The most interesting result of this brief overview of our preliminary analysis concerns the significantly lower number of deaths in the first year of life among the children of the people who survived to become centenarians: see Table 3. Ninety-six out of 1,000 infants of fathers who became centenarians died, and for mothers the figure is 79 per 1,000. By contrast, the death rates of the infant children of the controls who died in their 60s or 70s were 100–102 and 118–172 per thousand, for fathers and mothers respectively. The mothers who became centenarians also suffered lower death rates among their infant children than women born in later cohorts, even though infant mortality was lower in these later cohorts. The people in the 1918–1925 cohorts are less selected because the infant mortality had begun to decline in the depths of the demographic transition when there was a fertility decline.

In Sardinia as a whole, infant mortality in the period 1925–30, which roughly coincides with the mean age when centenarians had their children, was 100-105 per thousand (Gatti 2002; Breschi and Fornasin 2008).

6. Conclusions

The wealth of information gathered in the AKeA2 survey can be used to study various hypotheses about longevity.

So far, a number of noteworthy points have emerged. Women who live longer have on average fewer children, and at an older age, particularly for their last child. Perls et al. (1997), having observed that women of extreme longevity have had children after the age of 40, have suggested that the selective forces that tend to prolong life in human beings also tend to maximize the length of the reproductive period. Some studies in Sardinia on the relation between the age of women and the birth of their children and the risk associated with maternity at an advanced age have shown a high spatial variability in some variables indicative of reproductive longevity (Astolfi et al. 2009; Tentoni et al. 2012), with an aggregation of some municipalities constituting a central area of the island characterized by reproductive longevity coinciding with that of the longevity of the population previously obtained (Caselli and Lipsi 2006; Poulain et al. 2004). The relationship between longevity and fertility has been tackled in other papers and our preliminary findings confirm results that are reported elsewhere (Perls, Albert, and Fretts 1997; Doblhammer and Oeppen 2003; Doblhammer 2000; Larke and Crews 2006; Lycett, Dunbar, and Voland 2000; McArdle et al. 2006; Müller et al. 2002; Vinogradov 1998; Westendorp and Kirkwood 1998; Zeng and Vaupel 2004). Unlike previous studies, however, we focus on centenarians, and here lies the novelty. Centenarians, especially women, seem to have been favored by both a lower fertility distributed over a wide range of their fertility period, and by the young age of their

parents at the time of their own procreation. The centenarians appear to take advantage of several factors related to the timing of fertility that the literature suggests may foster longevity.

7. Acknowledgments

Corrections:

On May 30, 2015 a typing mistake on page 1056 was corrected at the authors' request.

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