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Late reproduction behaviour in Sardinia: spatial analysis suggests local aptitude towards reproductive longevity

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Abstract

Evolution in human life-history traits is influenced by environmental factors and, when genetic components underlie the relations, by micro-evolutionary forces. Age at reproduction is largely influenced by the familial cultural context and socioeconomic level, besides the maternal well-being and genetic background. The Sardinian population is characterized by historico-geographical isolation and differentiates from Italian mainland and other European populations in bio-demographic and cultural characteristics, among which the tendency to delay maternity persisting through generations. In our study, we investigated whether, in Sardinia, areas of "reproductive longevity" exist, where a higher-than-average incidence of late maternities combines with a lower-than-average cost in terms of perinatal death. Data from the Italian Central Institute of Statistics regard all 1980–1996 Sardinian births. Using spatial analysis of late maternity (proportion of babies born to mothers aged ≥35 years) and associated perinatal mortality (proportion of babies stillborn and dead within 0–6 days born to mothers aged ≥35 years), we aimed at singling out areas where the indicators run high and low, respectively. The perinatal mortality cost associated with the advanced maternal age [odds ratios (95% CI)] was evaluated through multiple logistic regression models. We identified central inland excess areas qualified by higher incidence of late maternities (27% vs. 22% in nonexcess area) and lower cost in perinatal mortality [OR=1.38 (1.04–1.84) vs. OR=1.74 (1.55–1.96) in nonexcess area]. In these "reproductive longevity" areas, the inbreeding coefficient was 3.7-fold higher than in the nonexcess areas, suggesting possible population homozygosity in genetic factors affecting the trait. Further and deeper investigations on biological and environmental determinants could focus on these target areas.

Keywords: Late fertility; Reproductive success; Risk at birth; Human reproduction; Reproductive fitness

1. Introduction

Cultural, socioeconomic and biological factors influence the evolution of human life-history traits and can affect individual fitness in terms of fertility as well as progeny health and survival. In addition, if genetic factors underlie the relation between the above determinants and life-history traits, population structure and micro-evolutionary forces, such as mutation, genetic drift and selection, can lead to evolutionary changes and, consequently, to intra-specific heterogeneities. In terms of evolutionary fitness, natural selection is expected to favour high fertility, early age at first reproduction and late age at last reproduction. However, its role is largely influenced by several factors, such as maternal well-being and health status, biological and genetic characteristics, familial wealth and socio-economic level. Among the cultural factors which contribute to modifying maternal life history, the tendency to delay reproduction has been widely spreading in the Western populations during the last 20 years, driven by the improvements in education and reproductive autonomy of the women as well as by their pursuit of social and economic success.

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Because of the concurrence of biological, cultural and socioeconomic determinants, evaluation of the genetic components and of the strength of natural selection on female life history is an exacting task. As for age at last reproduction, a study on Australian twins reported heritability estimates for age at menopause (Kirk et al., 2001), and investigations on preindustrial Finns estimated significant heritability and additive genetic variation for female life-history traits. In particular, differences were highlighted in the selective pressure on the end of the reproductive period, according to the wealth classes (Pettay, Kruuk, Jokela, & Lummaa, 2005; Pettay, Helle, & Lummaa, 2007).

The postponement of reproduction, in spite of its relevant costs in terms of offspring survival, child and mother health (Fretts, Schmittdiel, McLean, Usher, & Goldman, 1995; Jolly, Sebire, Harris, Robinson, & Regan, 2000; Joseph et al., 2005; Tarin, Brines, & Cano, 1998; van Katwijk & Peeters, 1998), is a widespread characteristic in the Sardinian population. Several peculiar traits, resulting from Sardinia's geographical and historical isolation, make the island population different from continental Italy as well as from other European countries and have been reported to cause demographic, biological and genetic differentiation among municipalities (Cavalli-Sforza, Menozzi, & Piazza, 1994; Zei et al., 2003). Among these distinctive traits, we can include the socio-economic context based on the patriarchal structure of the family and the sheep-rearing economy, the high endogamy and low immigration rate (Golini, 1967), the consequent genetic makeup that is also partially determined by the past malaria endemia (Caglia et al., 1997; Modiano et al., 1986), the historical demographic characteristics of high and late fertility, the still present tendency to postpone marriage and childbearing (Astolfi, Ulizzi, & Zonta, 2002; Golini, 1967; ISTAT, 1990-1997; Livi-Bacci, 1977; Zei, Lisa, & Astolfi, 1990), and the rates of high and exceptional longevity (Caselli & Lipsi, 2006; Gatti & Salaris, 2004; Poulain et al., 2004).

These considerations led us to investigate whether in Sardinia local differentiations can be evidenced in the reproductive behaviour and associated outcome. More precisely, we aimed at exploring whether the female tendency to delay childbearing is heterogeneously distributed in the island, and whether areas qualified for "reproductive longevity" exist where a higher incidence of elderly mothers combines with a lower cost in terms of perinatal deaths, due to a reduced impact of late maternity on the chance of delivering a healthy child.

Using 1980–1996 Sardinian birth records, we first defined two indicators of late childbearing and perinatal death, and computed smoothed estimates to reduce their spatial instability (Cressie, 1993; Lawson, 2001). Second, through isopleth maps, we represented the spatial course of the late maternity indicator as a continuum, not limited by administrative boundaries, and singled out critical areas of high incidence. Finally, through a qualitative graphical matching procedure and a quantitative evaluation of the risk of perinatal death associated with late maternal age, we explored whether such areas could be qualified for late and successful childbearing.

2. Data and methods

2.1. Birth and perinatal death data

Data came from birth and death (within 0–6 days) records of the Italian Central Institute of Statistics (ISTAT) and concerned all the Italian babies born from 1980 to 1996. Due to changes in the national birth registration policy, no more recent data were available. According to the privacy law, the individual records were provided by ISTAT coded by two consecutive time periods (1980–1989 and 1990–1996), area of birth event (Sardinian municipalities or mainland), six classes of maternal age (<20, 20–24, 25–29, 30–34, 35–39, 40–44, ≥45 years), level of maternal education (low for the compulsory school diploma and high for the secondary high school diploma or the university degree) and parity (first, second, third and later). Sardinian birth and death records corresponded to 363 municipalities, the smallest administrative areas which remained invariant during the overall time period, except for few aggregations.

From the dataset, we excluded records with missing information on maternal age and/or education and multiple births, which accounted for 1.67% and 2.04% in Sardinia and the mainland, respectively, to avoid their confounding effect in the evaluation of the perinatal mortality risk. The final sample size consisted of 9,534,374 births, of which 302,077 occurred in Sardinia.

The study focused on the second- and later-born children to avoid the confounding effects of maternal pathological conditions and subfertility status, often associated with the first parity at advanced age. From the data aggregated over the whole period (1980–1996), we evaluated a "late maternity" indicator as the proportion of babies born to elderly mothers aged ≥35 years, and in these babies a "perinatal mortality" indicator as the proportion of stillborn and dead babies within the sixth day of life. The choice of combining stillbirths and deaths within 0–6 days into a single indicator of perinatal mortality was based on the assumption that these deaths can be ascribed to similar causes, more likely associated with maternal endogenous factors of biological and genetic origin, and less influenced by the environmental and sanitary contexts and their temporal variations (Hart, 1998; Zonta, Astolfi, & Ulizzi, 1997).

2.2. Methods

To find out whether some parts of the island were characterized by unusual values of the late maternity and perinatal mortality indicators, we explored and compared their spatial distributions. The approach we adopted exploits ideas and methods from spatial data analysis (Cressie, 1993; Lawson, 2001; Silverman, 1986) and qualitative spatial reasoning (Bailey-Kellog & Zhao,