International Journal of Paleopathology xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Paleopathology

journal homepage: www.elsevier.com/locate/ijpp

Research Article

Cementochronology and sex: A reappraisal of sex-associated differences in survival in past French societies

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ARTICLE INFO

Article history:
Received 23 July 2014
Received in revised form 16 April 2015
Accepted 21 May 2015

Keywords:
Cementochronology
Sex-specific survival
Late Antiquity
Middle Ages
Maternal mortality
Tuberculosis

ABSTRACT

The objective of the present study is to test our general knowledge of sex-specific survival differences in past northern France societies by implementing the tooth cementum annulations method of age estimation (i.e., cementochronology) to bio-archaeological series. 1255 individual estimated ages at death covering a millennium from the 3rd c. AD to the 15th c. AD matched different patterns of sex mortality from the late Antiquity to the Late Middle Age. Female survival curves are consistently inferior to those of their male counterparts. Maternal mortality is clearly visible in survival curves between 20 and 50 years of age in individual sites and pooled samples. Variations of sex mortalities also affected sites with peculiar recruitment, such as religious communities, pathological samples, leprosaria, and migrants. Whisker plots of median ages at death variations confirmed in both sex that populations within the Early Middle Ages were better off compared to Late Antiquity and Late Medieval Ages when group inequalities prevailed. Due to its sensitivity and applicability to small samples, cementochronology should be extended to other series.

1. Introduction

A major demographic phenomenon in human evolution has been the impact of mortality control from the mid-18th century onwards in Western countries and the gradual increase in life expectancy of females relative to males. It is often considered the main effect of the sanitary transition (Blum et al., 1992; Caldwell, 1993). This can be seen through the positive evolution of female survival curves compared to males in the past 100 years (Meslé and Vallin, 2002; Wilmoth, 1997; Wilmoth et al., 2000), as illustrated for instance for Spain (Gómez-Redondo and Boe, 2005) (Fig. 1). According to the authors,

> "*We are witnessing, in Spain as in all countries with health advanced level to a squaring of the survival curve (. . .). Fig. 1 shows, not only, how the survival curves for men and women, still relatively close hundred years ago or even after the Second World War, have considerably diverged, but that the female curve is much more strongly squarized than male, due to a higher concentration of deaths in higher ages*".

Indeed, that sex difference in mortality rates is supposedly due to genetic, physiological, behavioral, and social causes (Caldwell, 1986).

In France, especially northern France, demographic historians (Bardet et al., 1981; Biraben et al., 1988; Biraben and Lévy, 1987; Gutierrez and Houdaille, 1983; Séguy, 1998, 1994) have explored male and female life expectancy through parish and civil registers in numerous towns and cities from the 16th and 17th centuries. Their results confirm a progressive decrease in maternal mortality combined with an increase in life expectancy after 45 years of age, especially at the end of the 18th century. On the other hand, these studies suggest an increase in male mortality and variability in overall adult mortality. These trends are comparable in other countries such as Switzerland (Perrenoud, 1981) and in most Western European countries. Some demographic historians (Bardet and Dupâquier, 1997) assume a balanced mortality by sex before the industrial transition, but they do not demonstrate actual data to support their hypothesis.

The demography of populations without written records, known as paleodemography, whether or not conducted in the context of modern documentary demographic data, however, failed

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http://dx.doi.org/10.1016/j.ijpp.2015.05.001
1879-9817/

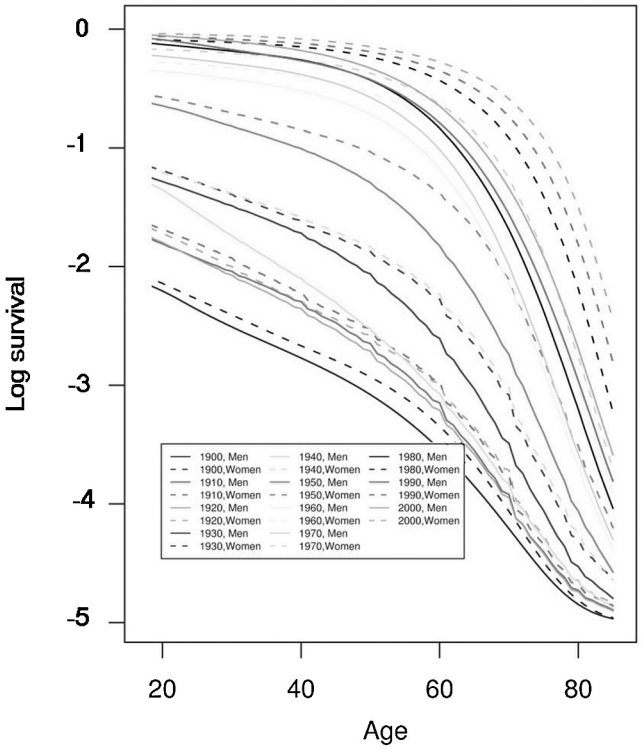

Fig. 1. Changes in survival curves of men and women in Spain during the twentieth century.
Source: INE, 2005.

to identify data that investigators could use to detect variations proposed for the 17th century and beyond (Alduc-Le Bagousse and Blondiaux, 2002; Mafart, 1994).

The knowledge of hazards for women in past populations is impaired by two obstacles confronted by bio-archaeological data. The first and most important is the low correlation between chronological age and standard anthropological age indicators (Bocquet-Appel, 2008). The second is the preservation state of skeletal remains (Bello et al., 2006), which can affect our ability to statistically control maternal and infant mortality due to taphonomic preservation of fetal bones. Since the development of transition analysis (Boldsen et al., 2002; DeWitte, 2010; Redfern and DeWitte, 2011; Sullivan, 2004) and the multimodal Bayesian and parametric approaches advocated in the Rostock protocol (Hoppa and Vaupel, 2002; Séguy et al., 2013), papers explored issues of mortality and sex and tried to draw conclusions on results despite the high standard errors linked to these methods. The absence of survival curves (DeWitte, 2010) or succinct mortality curves with only three age classes (Sullivan, 2004) are however hardly convincing. Recent reconstructions of survival functions from single or pooled samples (Redfern and DeWitte, 2011; Séguy et al., 2013, p. 201) are probably a more promising approach to explore differential mortality patterns. Since researchers are unable to assign a precise individual age-at-death, especially for adults, they are often unable to reconstruct and compare samples, especially small ones. In another domain but in a comparable perspective, Wright and Yoder (2003) raised the issue of the osteological paradox and the uncertain future of paleoepidemiology as long as no individual age estimation method could be developed.

Cementochronology as a method of adult individual age estimation has demonstrated in its latest developments (Kagerer and Grupe, 2001, p. 200; Wittwer-Backofen et al., 2004) and recent applications (Blondiaux et al., 2006) the highest correlation of estimated age to chronological age (up to 0.94). The taphonomy issues (Bello et al., 2006) can be partly avoided due to the usual better preservation of teeth when compared to skeletal parts in general.

The purpose of this study is to apply cementochronology to samples from Late Antiquity, the Early Middle Age, and the Late Middle Ages in order to test adult sex-specific survivals in northern France.

2. Material and methods

2.1. Material

The cementochronology technique was applied to 28 series from Late Antiquity to the Late Middle Age in northern France totaling 3571 individual bone assemblages with various conservation states (Table 1 and Fig. 2). Most of these skeletal collections has been studied by the first author (JB) and are currently curated at the Center for Paleopathological Studies (CEPN). 2466 adults are present with 1255 of these presenting at least one tooth for cementochronology analysis. Among these, sex diagnosis has been possible for 1031 individuals according to the Bruzek technique (Bruzek, 2002), and 224 remain unidentified. Each site has been attributed a settlement type (i.e., rural or urban) and sometimes an activity category (i.e., peasants, workers, military, migrants, or religious) depending on the archaeological context. In addition, the position and type of burial and the quality of grave goods were used to categorize the sites and to help interpret the demographic results.

The 28 sites are distributed into three chronological periods: Late Antiquity (LA) with 11 sites and 526 adults analyzed (Table 2); Early Middle Age (EMA) with 11 sites and 564 adults (Table 3); and Late Middle Age (LMA) with 6 sites and 165 adults (Table 4). Tables 2 and 3, and 4 also give a detailed distribution by sex, median age at death (MAD) for each sex and standard errors, in order to better interpret the survival curves.

2.2. Methods

2.2.1. Cementum histological technique

Each tooth was included in the epoxy resin (Araldite Brot). Each block was reduced by grinding to allow fast cutting in the middle third of the root (eight transversal sections for each tooth of 80–100 microns) with a micrometer saw (Buehler Isomer). Each non-polished section was placed between a slide and cover with three drops of Canada balsam. Each field is observed in normal light at 200x magnification on a Nikon Labophot microscope equipped with a digital camera. 20 microscopic fields per tooth were selected, and then each image was displayed on a computer with Adobe Photoshop. The modal account added to the average date of eruption

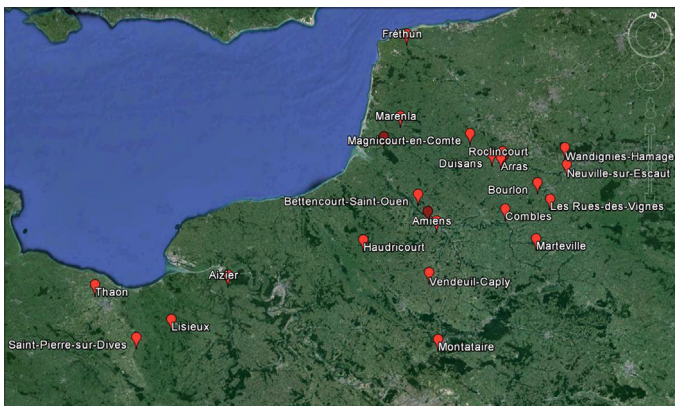

Fig. 2. Map of the sites studied for cementochronology.