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Patterns of frailty in non-adults from medieval London☆

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ABSTRACT

Famine has the potential to target frail individuals who are at greater risk of mortality than their peers. Although children have been at elevated risk of mortality during recent famines, little is known about the risks posed to children during the medieval period. This study uses burials from the St. Mary Spital cemetery (SRP98), London (*c.* 1120–1540) to examine the relationships among non-adult age at death, burial type (attritional or famine), and four skeletal lesions (porotic hyperostosis, cribra orbitalia, linear enamel hypoplasia [LEH], and periosteal new bone formation). Hierarchical log-linear analysis reveals significant associations between famine burials and LEH, independent of age. Significant associations also exist between age and the presence of cribra orbitalia, porotic hyperostosis, and periosteal lesions, with all three lesions present in greater frequencies among older children and adolescents, independent of burial type. The LEH results suggest that early exposure to stressors increased frailty among non-adults in the context of famine. The associations between age and the other skeletal indicators suggest that, in both famine and non-famine conditions, frailer individuals died at younger ages and before skeletal lesions could manifest, while their less frail peers survived multiple physiological insults before succumbing to death at older ages.

1. Introduction

Famine, traditionally recognized solely as a period of food shortage and mass starvation, has recently received attention among social scientists as a complex convergence of factors causing excess mortality within a population (Horocholyn and Brickley, 2017). Scholars now recognize that a prolonged food shortage or nutritional deficiencies can be caused or worsened by social and political factors (e.g., war, market panic, communication or transport failure) as well as environmental factors (e.g., droughts, crop diseases), which collectively prompt excess mortality within the affected population (Sen, 1981; Morgan, 2013). In addition to food shortages and death by starvation, malnutrition is known to weaken the body's immune defenses, heightening its susceptibility to disease and parasitic infection (Walter and Schofield, 1989; Maharatna, 1996; Ó Gráda, 2007; Morgan, 2013). Thus, famine is better defined as a prolonged food deficiency caused by environmental, social, and political factors, which leads to a variety of physiological and social outcomes, such as malnutrition and starvation, increased infectious disease susceptibility and mortality, migration, and community breakdown. Famines were common in medieval London, due to urban growth and a heavy reliance on imported food from the surrounding rural areas (Dyer, 2002). Farr (1846) amassed data on famines throughout the medieval period (9th–15th centuries), finding that the English experienced approximately 10 years of famine per century. Changing weather conditions and climatic events resulted in crop failures and thus famines during this period. For example, a volcanic eruption in the tropics is implicated in the production of excessive rain and flooding and consequent famine in 1257–1258 in England. These famines were frequently exacerbated by pestilence or infectious disease (Scrimshaw, 1987; Campbell, 1992; DeWitte and Slavin, 2013). Mortality during the 1257–1258 famine, for example, was compounded by an outbreak of infectious disease in 1259, which further increased the death toll attributed to the famine in England's largest urban center (Stothers, 2000). Similarly, the Great Famine in England (1315–1317) was believed to be caused by heavy rains that devastated harvests from 1314 through 1317, but was worsened by market failure and grain hoarding (Kershaw, 1973; Campbell, 2010). In sum, the excess mortality associated with famines in London during the medieval period included disease-related deaths, in addition to those more directly linked to food scarcities and starvation. As the Great Famine of 1315–1317 demonstrates, political and economic factors could intensify famine characteristics like food deprivation and infectious disease, which often biases famine mortality against a society's marginalized individuals (Sen, 1981). Many of the individuals who perished during famine events were rural-urban migrants and the urban poor, who could not afford the exorbitant grain prices in London during a

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prolonged shortage (Farr, 1846; Stothers, 2000).

Previous investigations of famine-related mortality among adults in medieval London have revealed associations between burial type—-specifically those individuals included in famine burials compared to individuals interred in attritional burials—and various osteological indicators of frailty, including femur length, linear enamel hypoplasia (LEH), and periosteal new bone formation (periosteal lesions). One study using skeletal material from St. Mary Spital cemetery (SRP98, *c.* 1120–1540) found that LEH in adults was significantly associated with famine burial (independent of age or sex), suggesting that early exposure to physiological stress increased the risk of mortality during famines experienced as an adult (Yaussy et al., 2016). Another study using the same skeletal assemblage found that a higher proportion of adults with short femora were included in famine burials (independent of age or sex), indicating that individuals who experienced early life physiological insults severe enough to impact growth were at increased risk of mortality during famines (DeWitte and Yaussy, 2017). In contrast, periosteal lesions on the tibia were significantly associated with non-famine (attritional) burials. This result might suggest that, during non-famine periods, individuals were better able to survive the factors that cause periosteal new bone formation long enough to develop these lesions, whereas individuals exposed to such factors in the context of nutritional stress and acute disease during famine periods died before such stressors formed (Yaussy et al., 2016; Jones et al., 2012). Although informative, these previous bioarchaeological studies of famine mortality in medieval London were restricted to adult skeletal remains, and have not provided any information about the risks experienced by children under famine conditions. A pair of studies examining victims of the Great Irish Famine (A.D. 1845–1852) suggested that mortality was particularly pronounced among non-adults (< 18 years old), especially among non-adults who exhibited skeletal indicators of physiological stress, such as scorbutic lesions, Harris lines, and growth retardation (Geber and Murphy, 2012; Geber, 2014). However, Geber (2014) cautiously highlights the context of the skeletal assemblage used for the studies, noting that the physical and psychosocial environments in a union workhouse likely impacted the patterns of morbidity and mortality observed in the sample. Consequently, the results of the Great Irish Famine studies are revealing, but not necessarily generalizable to populations from other temporal or geographic contexts.

Information from recent historical famines suggests that famine mortality exhibits peaks in the youngest and oldest age categories (Scrimshaw, 1987; Chamberlain, 2006; Morgan, 2013). Mortality during recent famines has been concentrated among children between the ages of 5–9 years and adults over the age of 45 years (Watkins and Menken, 1985), and this pattern is broadly consistent regardless of spatial, temporal, and cultural differences (Maharatna, 1996). Scholars suggest the most dangerous years for children to experience famine are the post-weaning years, when breast milk no longer confers nutritional and immunological benefits (Stuart-Macadam, 1995; Maharatna, 1996). However, though evidence suggests that post-weaning non-adults have been at greater risk of famine mortality in the last several centuries, little is known about the risks to non-adults during the medieval period. Much of the surviving historical documentation from this period is biased towards wealthy adult males (Kowaleski, 2013), and little is known about the health and mortality patterns of children at the time. However, skeletal samples can provide valuable information about the heterogeneity in frailty of non-adult individuals living during the medieval period (e.g., Lewis, 2002; Lewis and Gowland, 2007; Lewis, 2016). This study examines famine burials from medieval London and compares them to non-famine (attritional) burials from the same time periods. By using the available skeletal evidence, we recover data on a population that was widely omitted from historical documents and broaden our understanding of the selectivity of famines among children and adolescents in the past.

For this study, skeletal material from St. Mary Spital cemetery (SRP98, *c.* 1120–1540) is used to evaluate the associations between non-adult age at death, burial type (attritional or famine), and four skeletal indicators of exposure to physiological stress (porotic hyperostosis, cribra orbitalia, LEH, and periosteal new bone formation). Previous analyses of subadult data from St. Mary Spital by the Museum of London (Jones et al., 2012) revealed variable patterns of skeletal stress markers by age, burial type, and time period of use within the cemetery (see details below). In order to increase statistical power, we pool data across time periods. Further, we use an analytical approach (hierarchical log-linear analysis) that allows us to control for the potential effects of age on patterns of skeletal stress markers.

2. Materials and methods

2.1. Skeletal sample

The sample for this study come from the St. Mary Spital cemetery (SRP98), which was excavated by Museum of London Archaeology (MoLA) between 1998 and 2001. Associated with the Augustinian monastery and hospital of St. Mary Spital (founded in A.D. 1197 and closed in A.D. 1539), the cemetery was the final resting place for a diverse array of individuals, including hospital inmates, travelers, and wealthy benefactors. St. Mary Spital served London's ailing residents, but also provided alms to the poor, assistance to women in childbirth, shelter to pilgrims and migrants from the surrounding rural areas, and housing for orphans, widows, servants, and affluent elderly individuals (Thomas et al., 1997; Connell et al., 2012). Although only a portion of the cemetery could be excavated, 10,516 skeletons were recovered from the site, making SRP98 one of the largest excavated burial collections from Europe's medieval period. Archaeological context and a Bayesian approach to radiocarbon dating were used to divide the site into four phases: Period 14 (A.D. 1120–1200), Period 15 (A.D. 1200–1250), Period 16 (A.D. 1250–1400), and Period 17 (A.D. 1400–1539) (Sidell et al., 2007; Connell et al., 2012). In addition to the four chronological phases, MoLA used the number and arrangement of bodies in each grave to divide the interments into four distinct burial types. About half of the individuals buried in SRP98 were recovered from single graves (Type A), while the other half consisted of multiple interments arranged horizontally, vertically, or horizontally and vertically (Types B, C, and D, respectively) (Connell et al., 2012). Additional information about SRP98, as well as relevant images, site maps, and illustrations, can be found in the site report published by Connell et al. (2012).

Unlike the smaller B and C burial types, the multi-layered Type D burials held as many as 45 individuals and were hastily dug to accommodate a sudden rise in mortality within a period of days. Therefore, the Type ABC burials are described in the SRP98 site report as "the attritional group", and the Type D burials are referred to as "the catastrophic group" (Connell et al., 2012; Jones et al., 2012). There is no indication that the Type D burials exhibit more evidence of interpersonal violence than the Type ABC burials, which suggests that the mass burials were not used to inter the victims of warfare. Rather, the demographic profile of the Type D burials matches what would be expected during a famine event (i.e., mortality increases among non-adults and the elderly) (Jones et al., 2012). Although osteological age estimation methods have prevented an estimate of the mortality peak among older adult individuals, the Type D (famine) burials contain a greater proportion of non-adults compared to the Type A (attritional) burials (Table 1 provides the age-distributions in Type A and Type D burials in the Periods used in this study, as detailed below). In addition to the osteological data, radiocarbon dating shows that many of the Type D burial pits were dug prior to historically-documented outbreaks of plague in London, such as the Black Death of 1348–1350 (Jones et al., 2012). Instead, the dates of the Type D burials closely coincide with famines recorded by Farr (1846). For example, two mass burial pits from Period 14 were dated to *c.* 1155–1165, which closely coincides with a famine that occurred in 1162. Likewise, mass burials from Periods 15 and 16 were dated to *c.* 1235–1255, matching two closely-