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RESEARCH PAPER

Wealth, health and frailty in industrial-era London

Sharon N. DeWitte[1], Gail Hughes-Morey[2], Jelena Bekvalac[3], and Jordan Karsten[4]

[1]*Department of Anthropology, University of South Carolina, Columbia, SC, USA,* [2]*Health Sciences Program, School of Health Sciences, The Sage Colleges, Troy, NY, USA,* [3]*Museum of London Centre for Human Bioarchaeology, London, UK, and* [4]*Department of Religious Studies and Anthropology, University of Wisconsin Oshkosh, Oshkosh, WI, USA*

Abstract

Background: Socioeconomic status is a powerful predictor of mortality in living populations, as status affects exposure or access to a variety of factors that impact health and survival, such as diet, healthcare, infectious disease and pollution.
Aim: This study examines the effect of socioeconomic status on mortality and survival in London during a period spanning the early 18th through mid-19th centuries. During this period, London experienced rapid industrialization and heightened class distinctions. This study examines whether low-socioeconomic status was associated with reduced survival at a time when the distinctions between social strata were peaking.
Subjects and methods: The samples for this study are drawn from three skeletal assemblages in London that represent lower and higher social strata. The upper socioeconomic status sample ($n = 394$) is from Chelsea Old Church and St Bride's Fleet Street (crypt assemblage). The low socioeconomic status sample ($n = 474$) is from St. Bride's Lower Churchyard (also known as St Bride's Farringdon Street). The effect of status on mortality and survival is assessed using hazard analysis and Kaplan–Meier analysis.
Results: The results reveal elevated mortality and reduced survival for lower socioeconomic status children, but no strong effect of status on adult mortality or survival.
Conclusion: These results might indicate strong selective mortality operating during childhood or the effects of migration in the industrial-era population of London.

Keywords

Hazard analysis, industrialization, paleodemography, socioeconomic status, survival and mortality differentials

History

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Introduction

Socioeconomic status is considered one of the most powerful predictors of mortality (Cavigelli & Chaudhry, 2012; Saunders & Hoppa, 1993) because, although it is not a direct cause of mortality itself, it mediates access to resources that are essential for growth, development, tissue maintenance and immune response (Floud et al., 1990; Martorell & Habicht, 1986; Nicholas & Steckel, 1991; Robb et al., 2001; Schell, 1997; Stinson, 2000; Steckel, 2009). Those from the highest social strata are typically taller and healthier than those from the lowest social strata, and these advantages are attributed to adequate nutritional resources, access to healthcare and more hygienic living conditions resulting in decreased exposure to infectious diseases (Floud et al., 1990; Tanner, 1994). Presumably, this results in increased risk of morbidity, and ultimately mortality, for those whose access to vital resources is most restricted. This study examines the relationship between survival and mortality and socioeconomic status in skeletal samples from early modern London (1700–1853) to determine if low-socioeconomic status was associated with reduced survival and elevated mortality at a time when the distinctions between social strata were peaking.

Correspondence: Sharon DeWitte, Department of Anthropology, University of South Carolina, 817 Henderson Street, Gambrell Hall 440, SC 29208, USA. Tel: (803) 777-6500. Fax: (803) 777-0259. E-mail: dewittes@mailbox.sc.edu

Status differentials in living populations

Many studies have found evidence for poorer health and higher mortality among low socioeconomic groups in living populations. For example, in many countries socioeconomic status is strongly, positively associated with life expectancy and negatively associated with risks of mortality (Cavigelli & Chaudhry, 2012; Phelan et al., 2010; Robertson et al., 2013). Many diseases, such as cardiovascular disease, diabetes, cancers and infectious diseases, are found at higher prevalence in low socioeconomic status groups, and pathogen burdens are also higher for people of low socioeconomic status (Cavigelli & Chaudhry, 2012). Risk factors that are associated with low socioeconomic status include reduced access to healthcare, poor quality diet, engaging in health-compromising behaviours (e.g. smoking and inadequate exercise) and exposure to pollutants and toxins in homes and neighbourhoods (Chen & Miller, 2013; Darmon & Drewnowski, 2008). Low socioeconomic status people are more likely to live in crowded, poor-quality housing and less likely to have access to safe, clean water (Evans & Kantrowitz, 2002). People who live in low socioeconomic status neighbourhoods are more likely to be exposed to violence, which, in addition to posing direct threats to health, also increases morbidity from diseases such as asthma and cardiovascular disease (Chen & Miller, 2013). Some studies have found increased glucocorticoid production (commonly used as a measure of physiological stress) in low socioeconomic status people, and chronic elevated glucocorticoid levels are associated with compromised cell-mediated immune responses (Cavigelli & Chaudhry, 2012). Researchers hypothesize that the relationship between low socioeconomic status and reduced longevity exists in part because of an increased rate of biological ageing; i.e. the physical, mental and behavioural stressors associated with low socioeconomic status increase the risk of cellular and genomic damage and there is some evidence of an association between socioeconomic status and telomere length (a measure of biological ageing) (Robertson et al., 2013).

Bioarchaeological evidence of status differentials

The bioarchaeological evidence for a relationship between health and socioeconomic status in past populations suggests the nature of this association may be context-specific, rather than universal. For example, Mays et al. (2009) did not find any relationship between long bone length (a proxy for stature and, therefore, health) and social status in a sample of children from St Martin's 19th century churchyard in Birmingham, England. Miszkiewicz (2015), on the other hand, found a greater frequency of dental enamel hypoplasia in the lower status cemetery sample as compared to the higher status priory sample in an 11–16th century skeletal sample from St Gregory's Priory collection from Canterbury, UK.

Grauer (1989) found no significant differences in chances of survival between higher and lower status sub-adults in the mediaeval British population of St Helen-on-the-Walls, but status did affect survival for adults. Based on patterns of skeletal stress markers, high status did not appear to shield individuals from physiological stressors, but, instead, improved their chances of surviving such stressors. Sullivan (2004) found that status and mortality were linked in a medieval sample from St Andrew's priory in Fishergate, York, but that the associations were not always in the direction one might expect. In this case it was middle status females, rather than high status males or females, whose lifespan matched that of the longest-lived religious males. High status males often died young from violent injuries in Sullivan's sample, highlighting that the relationship between mortality and social status may be more nuanced and, once again, context-specific, than is typically assumed. Miszkiewicz (2015) also identified a relationship between social status and longevity in the sample from St Gregory's priory. Those buried in the priory, a reflection of high social status, lived significantly longer than those buried in the associated cemetery, which was reserved for the lower social strata.

It is evident from previous research in this area that it is difficult, if not impossible, to expose all of the layers of hidden heterogeneity in frailty created by the social and political-economic contexts in which a population lived and died. Moreover, these contexts are generally not universal, but specific to a time period and geographic location. There is, however, one broad historical context that re-defined social relationships and shaped morbidity and mortality patterns for much of the modern world, and that is industrialization (Szreter, 1997, 2004). One of the many effects of industrialization is increasing inequality between the upper and lower classes (Lindert, 1994), which leads to increasingly distinct social strata. This was the case in industrializing England where those who had already built the capital to invest in emerging industries benefitted most from rapidly accumulating surpluses (Hill, 1985). The influx of would-be labourers from the countryside far exceeded the demands of manufacturing, leaving many hopeful young migrants under-employed or unemployed. The result was a city overcrowded with poor, young adults, wherein housing costs skyrocketed along with unsanitary conditions, widening the divide between the upper and lower classes (Hill, 1985; Porter, 1994; Williamson, 1994). The living conditions endured by those from the lower social strata would have had consequences for their health and potentially their survival.

This study assesses the influence of socioeconomic status on survival and mortality in skeletal samples drawn from the upper and lower social strata of the population of industrializing early-modern London (1700–1853). The age structures of burials in London parishes during this time period are available from the London Bills of Mortality (which provide totals of baptisms and burials from London parishes, with burials-by-age data available beginning in 1728). However, the Bills have defects such as including only those baptized by the Church of England and failing to include many abortives and stillbirths (Ogle, 1892; Woods, 2006). According to Ogle (1892), parish records sometimes included individuals who were not buried in the parish graveyard and (more frequently) omitted the deaths of persons who were buried there, and some parishes failed to send accounts for weeks or years at a time. In general, burials registered in Bills under-estimate deaths in London parishes (Razzell, 1994; Woods, 2006). Although skeletal assemblages are also vulnerable to their own sources of bias (e.g. incomplete excavation of a site or infant under-enumeration), they likely contain individuals who are missing from historical documents such as the London Bills of Mortality.

Materials and methods

Skeletal samples

Three skeletal collections from London, England, dating from the early 18th through mid-19th centuries were analysed for this study; their general locations are shown in Figure 1. The upper socioeconomic status sample ($n = 394$) is drawn from Chelsea Old Church ($n = 179$) and St Bride's Fleet Street (crypt assemblage) ($n = 215$) combined. The low socioeconomic status sample ($n = 474$) consists of burials from St Bride's Lower Churchyard, alternatively known as St Bride's Farringdon Street. These three collections are roughly contemporaneous and date from a time of rapid industrialization and heightened class distinctions (Crafts, 1994; Hill, 1985; Lewis, 2002; Lindert, 1994; Williamson, 1994).

Chelsea Old Church is located in a suburb of London long known for its affluence, as documented by the parish register that lists statesmen, scholars, duchesses and a variety of other

Figure 1. Map of approximate cemetery locations in London: (A) Chelsea Old Church, (B) St Bride's Fleet and St Bride's Lower Churchyard. Courtesy of Eric E. Jones.

prominent citizens (Cowie et al., 2008). Archaeological evidence offers further insight about the population of Chelsea between 1712–1842. Numerous coffin plates were recovered, of which 25 were legible and associated with an individual burial. A check of the parish register confirms that all 25 of these individuals were of high status. As a parish church, Chelsea Old Church accepted burials of both poor and wealthy individuals; however, the excavated area included more high status burials. These burials in the Chelsea Old Church cemetery were in lead lined coffins, brick lined shafts and vaults, all of which are indicative of higher social-status, as these treatments were more costly than the standard wooden box in an unlined, earth-cut shaft typical of the lower social strata. The Chelsea Old Church collection is presently curated by the Museum of London's Centre for Human Bioarchaeology (WORD database, 2012).

The St Bride's Fleet Street and St Bride's Lower Churchyard assemblages originate from a single parish, St Bride's Parish, Fleet Street (London EC4Y 8AU), that served the population of central London. The sample drawn from St Bride's Fleet Street includes named individuals from the crypt burials who were interred between 1740–1852 (our sample only includes the completely skeletonized remains from the crypt burials, as well preserved individuals with surviving soft tissue were reburied in the 1950s). Information from the parish register, coffin plates and historical accounts suggest those buried within these crypts were of high status (Milne, 1997). The skeletal remains are curated by St Bride's Church, in collaboration with the Museum of London Centre for Human Bioarchaeology (since 2009), and data collected by the Centre can be obtained therefrom upon request.

According to parish records, interments in St Bride's Lower Churchyard on Farringdon Street began in the 17th century in response to overcrowding at the St Bride's Fleet Street burial ground (Miles & Conheeney, 2005); according to archaeological evidence, the burials used in this study date to 1770–1849. Throughout history it has been typical practice to bury the poor at a greater distance from the church walls than the wealthy, who were afforded burial close to or within the church itself (Harding, 1998). This was the case at St Bride's Church, where poor parishioners were buried in the lower cemetery at greater distance from the church, while wealthier parishioners were buried in crypts on the church grounds (Milne, 1997). The burials in St Bride's Lower Churchyard were earth-cut and in plain wooden coffins with very few furnishings, in stark contrast to the centrally located, lead coffined burials at St Bride's Fleet Street and similar costly burials at Chelsea Old Church. Parish records suggest this cemetery was the burial ground for not only poor parishioners, but also the deceased from Bridewell Workhouse and Fleet Prison, until its closing in 1849 (Scheuer, 1998). As with Chelsea Old Church, the skeletal remains from St Bride's Lower Churchyard are curated by the Museum of London's Centre for Human Bioarchaeology; data from both assemblages are available from the Museum of London Wellcome Osteological Research Database and can be obtained from the Centre (WORD database, 2012).

Age and sex estimation

Sub-adult (≤18 years) ages were estimated using a combination of dental eruption (Gustafson & Koch, 1974; Moorees et al., 1963a,b; Smith, 1991), diaphyseal length (Scheuer et al., 1980) and epiphyseal fusion methodologies (Scheuer & Black, 2000). When both dental and skeletal estimates were available, dental age was used because this has the strongest correlation with chronological age (Lewis & Garn, 1960). Juvenile age estimates from WORD are provided as interval estimates, with the exception of the perinatal category: 1–6 and 7–11 months, 1–5, 6–11 and 12–17 years. Age-at-death in adults was determined using degeneration of the pubic symphysis (Brooks & Suchey, 1990) and iliac auricular surfaces (Buckberry & Chamberlain, 2002; Lovejoy et al., 1985) and sternal rib end morphology (İşcan & Loth, 1986a,b). Adult age estimates from WORD are provided as interval estimates: 18–25, 26–35, 36–45 and 46+ years. As articulated by Bocquet-Appel & Masset (1982), traditional methods such as these are biased toward the age distribution of the known-age reference samples used to develop the methods. Traditional age estimates tend to over-estimate younger adult ages and under-estimate older adult ages and have broad terminal age intervals (Milner & Boldsen, 2012). Actual ages at death derived from coffin plates were available for 214 individuals (25% of the combined sample) from St Bride's Fleet Street, allowing for a comparison of traditionally estimated ages at death to actual ages at death. For comparative purposes, we assigned individuals with known ages at death to one of the age intervals described above based on their known ages. Logistic regression reveals that the estimated ages for this portion of the sample are very similar to the known ages (pseudo $R^2 = 0.93$). Only 15 of the 214 estimated age intervals differed from the true age interval and all but two of those were within one interval of the true age interval (the remaining two were within two intervals of the true age interval). The estimated ages at death from St Bride's Fleet Street were used for consistency, as actual ages at death are not available for the other cemeteries in this analysis. As described above, the age estimates from WORD are provided as interval estimates, with the exception of the perinatal category and the terminal category (46+). For these analyses, we use the mid-points of the interval estimates for individuals assigned to the age intervals, i.e. 0.3, 0.75, 3, 8.5, 14.5, 21.5, 30.5 and 40.5 years; we used 0 for individuals in the perinatal category. The terminal age category (46+) is open-ended and, thus, has no true mid-point, so we used an age of 50.5 for this interval in our analyses. It is possible that, by using this terminal age interval, we might under-estimate the true differences in mortality and survival between high and low status adults at later adult ages and we discuss the implications of this in our Discussion.

Sex was not estimated for sub-adults, as reliable estimation methods have not yet been developed (Scheuer & Black, 2004). Sex was estimated for adult skeletons using morphology of the skull (Acsádi & Nemeskéri, 1970) and pelvis (Phenice, 1969), and we used the sex and age-group divisions devised by Buikstra & Ubelaker (1994).

Statistical analyses

Hazard analyses

To determine whether socioeconomic status affected risks of death in London *circa* 1700–1853, burial in a high- vs low-socioeconomic status context was modelled as a covariate (burial in low-status context = 0, burial in high-status context = 1) affecting the parameters of the Siler model of mortality. The Siler model is a parsimonious five-parameter model of mortality that fits a wide range of human mortality patterns (Gage, 1988; Siler, 1979):

$$h(a) = \alpha_1 e^{-\beta_1 a} + \alpha_2 + \alpha_3 e^{\beta_3 a}$$

The first component of the Siler model, $\alpha_1 e^{-\beta_1 a}$, represents immature mortality, which typically is very high at birth and then decreases rapidly with age; the α_1 parameter specifies the mortality associated with infant and childhood causes of death and β_1 specifies the rate at which it changes with age. The second component of the model, α_2, is an age-independent component that is associated with causes of death that are unrelated to an individual's age (e.g. accidental causes of death). The last component of the Siler model, $\alpha_3 e^{\beta_3 a}$, represents senescent mortality, which is low at birth and younger ages, but increases with adult age; α_3 specifies the mortality associated with senescent causes of death and β_3 specifies the rate at which it changes with age. The three components of the Siler model are independent of one another, so surviving one component has no influence on risk of mortality during another component (Wood et al., 2002). Because the Siler model requires the estimation of a small number of parameters, it can be applied to relatively small samples (i.e. those common to bioarchaeology); it smoothes the random variation usually present therein, without imposing any particular age pattern on the data (Gage, 1988; Wood et al., 2002). This and similar parametric models are also suitable for use with datasets such as ours that include imprecise age estimates, particularly with respect to open-ended terminal age categories, as they allow for the estimation of patterns at later adult ages that would otherwise be inaccessible (Milner et al., 2008).

Social status was modelled as a covariate affecting the Siler model in two ways. The first approach models status as a covariate (0 = low status, 1 = high status) affecting the entire Siler model (i.e. status was modelled as proportional to the entire hazard, independent of age). However, the effects of status on risks of mortality might not be uniformly distributed across all ages and the aggregate pattern may mask important sub-population differences in risks of mortality (Vaupel & Yashin, 1985; Wood et al., 2002). Therefore, we also model status as a covariate affecting the juvenile and senescent components of the Siler model independently to allow for some variation with age in the effect of status on risk of mortality. Further, the catchment area for Chelsea Old Church cemetery was located further from the city of London than that associated with either St Bride's Lower Churchyard or St Bride's Fleet Street; Chelsea was not listed in the Bills of Mortality for London and was considered to be outside the confines of the City at the time. Given this and the spatial variation that existed in morbidity and mortality patterns within and around London *c.* 1670–1830 (Landers, 1993), we also restricted analysis to St Bride's Fleet Street vs St Bride's Lower Churchyard to verify that the results of our analyses truly reflect socioeconomic differences and not urban vs rural differences. The model parameters and their 95% confidence intervals were estimated using maximum likelihood analysis with the program *mle* (Holman, 2005). A negative estimate for the parameter representing the effect of the status covariate on the hazard would suggest that people of higher social status were at a decreased risk of death compared to lower-status individuals.

A likelihood ratio test (LRT) was used to assess the fit of the full model compared to a reduced model in which the value of the parameter representing the status covariate was set equal to 0. The LRT, therefore, tests the null hypothesis that high social status was not associated with elevated nor decreased risks of death (i.e. social status had no effect on risk of mortality). The LRT was computed as follows: $LRT = -2[\ln(L_{reduced}) - \ln(L_{full})]$, where LRT approximates a χ^2 distribution with df = 1. Although we are wary of reporting statistical significance, given recommendations by major epidemiological and medical journals to avoid doing so (Cohen, 2011; Goodman, 1999; Lang et al., 1998; Rothman, 1998), we consider p values less than 0.10 to be suggestive of a real effect. Our estimates (for hazard parameter estimates and our other analyses described below) should be viewed with caution given the error associated with age estimation. The actual numerical values of the estimates are, we argue, much less important than whether they reveal a consistent, interpretable pattern.

Kaplan Meier survival analysis

The effect of socioeconomic status (burial in low-status context = 0, burial in high-status context = 1) on survival was also assessed using Kaplan-Meier survival analysis with a log rank test and using pooled data on age from all cemeteries. Analysis was performed using SPSS version 21.

Social status was modelled as a covariate affecting survival in two ways. The first approach models status as affecting survival across all ages. However, because the aggregate pattern may mask important sub-population differences in survival, we also model the effect of status on sub-adult (<18) and adult (≥18) survival independently to test whether any observed differences are consistent from childhood through adulthood. As with hazard analysis, we also restricted analysis to St Bride's Fleet Street vs St Bride's Lower Churchyard to verify that the results of our analyses truly reflect socio-economic differences and not urban vs rural differences.

Fertility proxy

Given that cemetery age-at-death distributions are more sensitive to fertility than to mortality (Sattenspiel & Harpending, 1983), to control for fertility differences between the two status groups, this study uses the number of the individuals above the age of 30 divided by the number of individuals above the age of 5, i.e. D30+/D5+. Buikstra et al. (1986) found that there is a strong (negative) relationship between D30+/D5+ and birth rate and comparison of the 95% comparison intervals across samples reveals whether birth rates differ significantly among them.

This study makes the assumption that the population under investigation was stationary, i.e. closed to migration and having constant age-specific fertility and mortality rates, a stable age distribution and a growth rate of zero (Milner et al., 2008; Wood et al., 1992). Such an assumption allows paleodemographers to use skeletal age-at-death distributions to estimate mortality rates and other demographic patterns. However, this assumption, if violated, means that our estimates might be biased. This likely does not present a major limitation for our study given that we are looking at a relatively long time period, which will tend to lessen the effects of perturbations in fertility and mortality on the age-at-death distributions (Paine & Boldsen, 2006) and we are comparing sub-populations within a larger population rather than comparing two separate populations. However, ideally, we would use a model that allows for estimation of the population growth rate and, thus, make the less stringent assumption that our population was stable (a state that most populations tend towards), but that is beyond the scope of this paper. Further, migration was clearly occurring during this time period in London (Landers, 1990); we discuss the possible effects of migration on our results in the Discussion.

Results

The age-at-death distributions from the low- and high-status samples using (1) all three samples and (2) just the urban assemblages are shown in Figures 2 and 3. For consistency with the data used for survival analysis, individuals were placed into the 5- and 10-year age intervals used for the figures based on the mid-point age estimates described in the Methods, rather than the original WORD age-intervals. Using both combinations of samples, the low-status sample has a higher proportion of young children and a lower proportion of older adults compared to the high-status sample.

The estimated values of and the 95% confidence intervals for the parameter representing the effect of the social status covariate on the entire Siler hazard using all three samples and just the urban samples are shown in Table 1. The analyses of the effect on juvenile and senescent mortality separately, for both sets of samples, are shown in Table 2. Using both combinations of skeletal samples, when the status covariate is modelled on the entire Siler model (i.e. all ages are assessed

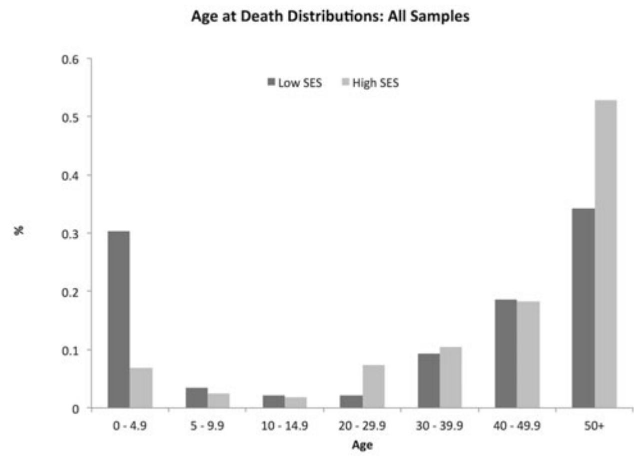

Figure 2. Age-at-death distributions from all samples, i.e. Chelsea Old Church/St Bride's Fleet Street vs St Bride's Lower Churchyard.

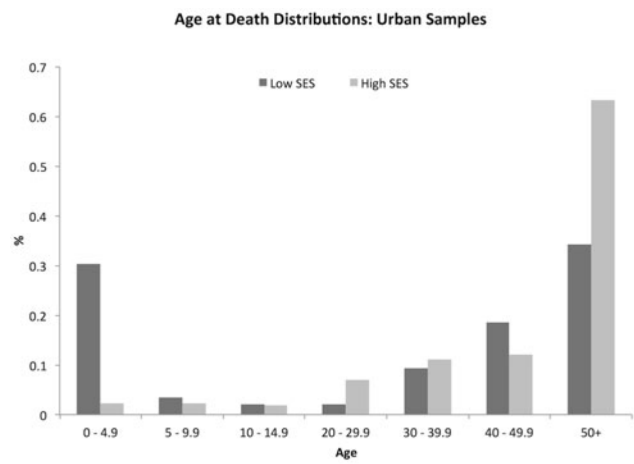

Figure 3. Age-at-death distributions from urban samples, i.e. St Bride's Fleet Street vs St Bride's Lower Churchyard.

Table 1. Maximum likelihood estimates (with 95% confidence interval in parentheses) of the effect of the status covariate on the Siler model and the results of the likelihood ratio test.

	Siler Hazard	−2LLR
All samples	−0.32 (−0.81, −0.27)	9.62 ($p = 0.002$)
Urban samples	−0.51 (−0.71, −0.28)	303 ($p < 0.001$)

All samples = Chelsea Old Church/St Bride's Fleet vs St Bride's Lower Churchyard; urban samples = St Bride's Fleet vs St Bride's Lower.

simultaneously, with no variation in the covariate effect across age), the results suggest that mortality risks in general were lower in the high-status sample. However, when status is modelled as a covariate separately on the juvenile and senescent components of the Siler model, the results indicate a lower risk for children in the high-status sample compared to the low-status sample, but no difference in risk of death between high- and low-status adults.

The Kaplan-Meier survival curves for the samples including individuals from all assemblages are shown in Figures 4–6 for illustrative purposes (the survival curves for analyses that included only the urban assemblages revealed similar patterns), and the results of the corresponding log rank tests for all analyses are shown in Table 3. Using both

Table 2. Maximum likelihood estimates (with 95% confidence interval in parentheses) of the effect of the status covariate on the juvenile and senescent components of the Siler model and the results of the likelihood ratio test.

	Juvenile mortality	Senescent mortality	−2LLR
All samples	−3.15 (−10, −1.56)	−0.02 (−0.26, 0.18)	131 ($p < 0.001$)
Urban samples	−0.61 (−1.32, −0.42)	0.48 (−0.14, 0.59)	4.63 ($p = 0.03$)

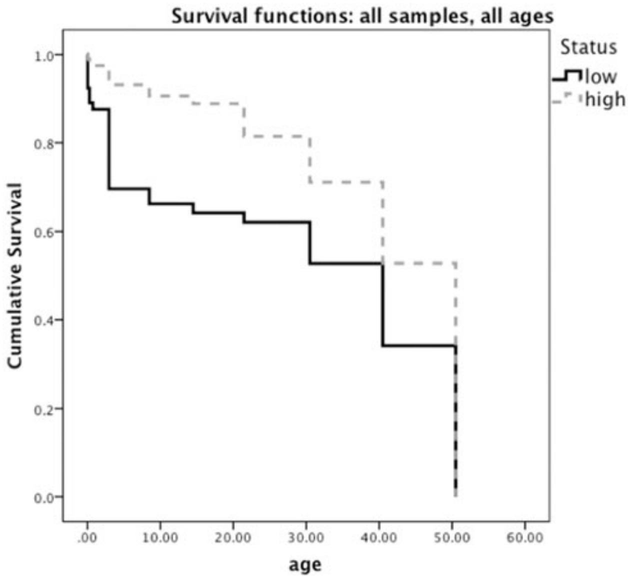

Figure 4. Kaplan Meier survival functions using all samples and all ages.

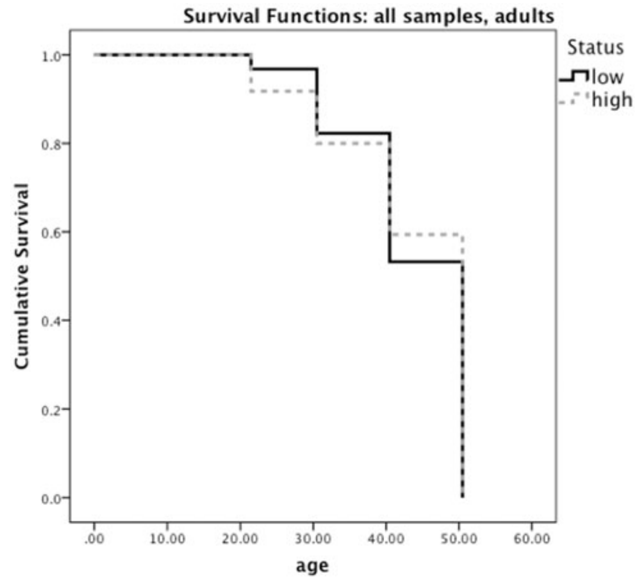

Figure 6. Adult Kaplan Meier survival functions using all samples.

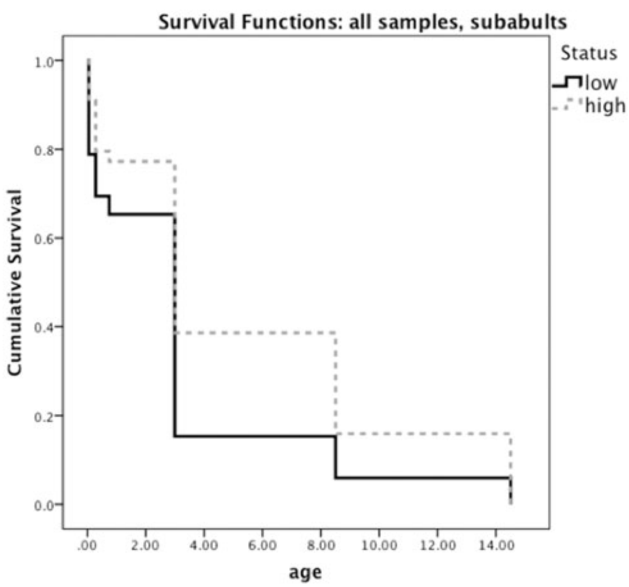

Figure 5. Sub-adult Kaplan Meier survival functions using all samples.

combinations of samples, there is a significant difference between the high and low socioeconomic status samples when all ages are included, with enhanced survival for the high status individuals. Similar results are observed when just sub-adults are evaluated; however, there is no significant difference between the high and low status adults.

The D_{30+}/D_{5+} values and their 95% comparison intervals are shown in Table 4. The comparison intervals for the two statuses overlap, which indicates a lack of a significant difference in birth rates between the two (Buikstra et al., 1986).

Discussion

There is little argument as to the nature of the relationship between socioeconomic status and mortality in modern populations, as there is ample evidence supporting the association between high status and decreased risk of mortality (Cavigelli & Chaudhry, 2012; Phelan et al., 2010; Robertson et al., 2013). The question of when this disparity emerged is more controversial (Bengtsson & Dribe, 2011; Bengtsson & van Poppel, 2011; Haines & Ferrie, 2011). Although it occurred at different times in different regions (Shiue & Keller, 2007; Steckel, 1999), the industrial revolution typically resulted in the crowded and unsanitary living conditions that are associated with ill health and, therefore, increased risk of mortality in modern populations (Chen & Miller, 2013; Darmon & Drewnowski, 2008; Evans & Kantrowitz, 2002). As such, industrialization has been suggested as a major force in the emergence of modern health gradients (Antonovsky, 1967) because wealth, in theory, secures a degree of protection (via access to medical care, adequate nutrition, less crowded housing and so forth) from threats to health. Some, however, argue that disparities in health and mortality between the wealthy and the poor, resulting from the unequal distribution of goods and services which favours the wealthy, have always existed and have changed little throughout time (Marmot, 2004). This model, which is referred to as the fundamental social-causes model

Table 3. Kaplan-Meier survival analysis results.

Sample	Social status	Mean survival time	95% CI	Mantel-Cox χ^2	p Value
All samples, all ages	Low	29.2	27.4–31.1	43.5	<0.001
	High	39.4	37.9–40.9		
All samples, sub-adults	Low	3.2	2.7–3.8	8.1	0.004
	High	5.5	4.0–6.9		
All samples, adults	Low	43.8	42.8–44.7	1.1	0.3
	High	43.7	42.7–44.7		
Urban samples, all ages	Low	29.2	27.4–31.1	55.2	<0.001
	High	42.3	40.5–44.0		
Urban samples, sub-adults	Low	3.2	2.7–3.8	11.8	0.001
	High	8.0	5.4–10.7		
Urban samples, adults	Low	43.8	42.8–44.7	6.6	0.01
	High	44.7	43.3–46.0		

Mean survival times and 95% CIs are in years.

Table 4. D_{30+}/D_{5+} values and their 95% comparison intervals for the low- and high-status samples.

	D_{30+}/D_{5+}	95% CI
Low status	0.89	0.81–0.98
High status	0.87	0.79–0.96

(Phelan et al., 2004) or the constancy hypothesis (Bengtsson & van Poppel, 2011), is countered by evidence for cycles of divergence and convergence in the mortality experiences of differing social strata, suggesting that the disease environment (e.g. highly virulent vs nutrition-dependent diseases) determines whether any particular social group has a mortality advantage at any given point in time (Antonovsky, 1967; Bengtsson & van Poppel, 2011; Woods & Williams, 1995).

The age-at-death distributions and results of hazard and survival analyses in our study indicate that there were important differences in mortality and, thus, health between the high and low socioeconomic status sub-populations in industrial-era London. The apparent lack of mortality and survival differences between high and low status adults might have resulted from differences in mortality and survival and, thus, health between the high and low status children in this population. Analysis of just the urban assemblages (St Bride's Lower Churchyard and St Bride's Fleet Street) yields results consistent with those obtained from all three samples, which confirms that these findings reflect a real pattern and are neither an artifact of comparing two samples from geographically distinct environments, nor an artifact of an urban mortality penalty (Cain & Hong, 2009; Gagnon et al., 2011).

Modern social gradients in mortality may have emerged during industrialization first in the sub-adult cohort, with adult mortality disparities arising as late as the first half of the 20th-century (Razzell & Spence, 2006). Our results support this assertion and indicate that the mortality disparities seen among adults in modern day England (Marmot et al., 1991, 1997) are a relatively recent development. One possible interpretation of our results is that there were no systematic health advantages associated with high status for adults during this time period. This could have been the case if high and low status individuals had equal access to the resources needed to mount sufficient immune responses, if they experienced similar exposures to diseases and other threats to health or if diseases and other causes of death killed indiscriminately.

Another possible interpretation of our results is based on the phenomenon of selective mortality. Mortality tends to be selective, such that individuals with the highest frailty (an individual's relative risk of dying compared to other people in the same population) are most likely to die from a variety of causes (Vaupel et al., 1979). In our study, the lower estimated risk of death and higher estimated survival of high-status children when compared to low status children and the lack of a difference in mortality and survival between high- and low-status adults might reflect selective mortality operating during childhood in the industrial-era population of London.

In industrializing London, high status likely had strong protective effects on children resulting in reduced frailty among high-status juveniles compared to their low-status peers. If mortality was strongly selective with respect to frailty during childhood in London, those people who survived childhood would have had lower frailty, on average, than the original cohort exposed to childhood mortality. By targeting children with the highest frailty, a large proportion of whom would likely have been of low socioeconomic status, selective mortality could have resulted in reduced differences in mortality and survival between high- and low-status adults.

The difference between these two interpretations of our results is subtle but important. The 'selective mortality' interpretation suggests that the later emergence of social differentials among adults does not necessarily reflect a lack of divergence in mortality in general among social strata throughout the industrial period. Rather, it might mean that the social gradient in mortality was so steep that the frailest of poor individuals died before achieving adulthood and, thus, only robust sub-cohorts of poor individuals survived to adulthood, whereas more heterogeneous cohorts of wealthy individuals survived to adulthood because their social position offered some degree of buffering from environmental insults. This would minimize differences in adult mortality between social strata because the adult cohort would consist of both frail and hardy wealthy individuals, but only the hardiest of poor individuals. The selective mortality interpretation means that we cannot examine mortality patterns at different stages of life in isolation, rather we must consider how mortality earlier in life can influence mortality at later ages (see Engelman et al., 2010). This interpretation also shifts the focus from the disease environment itself to the effects of the disease environment on the distribution of frailty among those who survive from one age to the next. In other words, it may be the allocation of risk within the population that varies, although the fundamental social causes of mortality disparities remain constant.

Studies from other geographic areas have also identified negative associations between social status and mortality among sub-adults (Breschi et al., 2011; Haines, 2011; Schumacher & Oris, 2011) before and during the process of industrialization. Further, the idea that low-status juveniles, in London in particular, had greater frailty than their high-status counterparts is supported by the previous work of one of the authors. Hughes-Morey (2012) examined the effects of socioeconomic status on the relationship between adult stature, presumably a summary measure of health status during childhood (Bogin, 1999; Eveleth & Tanner, 1990; Skerry, 1994; Stinson, 2000), and mortality in samples drawn from St Bride's Lower Churchyard and Chelsea Old Church cemetery. Females from St Bride's Lower Churchyard were significantly shorter, as expected based on their lower socioeconomic standing (Floud et al., 1990; Komlos, 2007; Steckel, 1987, 1995), than females from Chelsea Old Church. However, the same did not hold true for males, for whom there was no significant difference in stature between the social strata. Further, the often-cited inverse association between stature and risk of mortality (DeWitte & Hughes-Morey, 2012; Gage & Zansky, 1995; Gunnell et al., 2001; Kemkes-Grottenthaler, 2005; Steckel, 1995, 2005; Watts, 2011) was found only in the male sub-sample from Chelsea Old Church. Hughes-Morey (2012) suggests this pattern is the result of reduced frailty among high-status male children, whose wealth provided them with preferential access to resources essential for growth, immune response and survival (Bogin, 1999; Eveleth & Tanner, 1990; Golden, 1998; Martorell & Habicht, 1986; Stinson, 1992, 2000) and who may have benefitted from preferential parental investment as compared to female offspring (Voland et al., 1997). Ostensibly, this would result in an adult population in which high-status males were no taller, on average, than low-status males, because high-status males would be more likely to survive into adulthood even if their growth had been disrupted by illness, while low-status males whose growth had been disrupted would have been less likely to survive the offending illness. Only among high-status males was there potential to capture an association between stature and mortality in adulthood, due to the strong protective effects of high socioeconomic status during childhood.

There is evidence of severe physiological stressors, high mortality and, thus, potentially strong selective mortality during childhood in industrial-era London and in Britain more generally. In industrialized towns in northern England, infant mortality rose during the first half of the 19th century (Huck, 1995), for example, and Lewis (2002) found higher frequencies of stress markers indicative of foetal and childhood disease or malnutrition in a sample from industrial-era (1729–1859) London compared to mediaeval samples from both urban and rural locations in England. These results suggest the negative effects of industrialization, rather than urbanization alone, on the health of children in London. According to Komlos & Küchenhoff (2012), the height of English men declined rapidly with the onset of the industrial revolution, indicating general declines in nutritional status during development in this period. In the late 18th- and early 19th-centuries, there were dramatic gaps in height between the rich and poor in England, which indicate that declines in standards of living (e.g. reductions in real wages) during the 18th-century affected the nutritional status of the low-socioeconomic status people much more strongly than that of the high status people (Komlos, 2007).

There are numerous pathways through which high status may confer protective effects for children. During this period in London, high status children may have had better access to nutritional resources, clean water, healthcare and lived in less crowded and polluted and, therefore, less pathogenic, conditions (Clark et al., 1995; Mays et al., 2008), all of which could have served to decrease mortality. In particular, breastfeeding practices are known to vary by socioeconomic status (Fildes, 1988, 1995; Nitsch et al., 2011) and directly affect infant morbidity and mortality, with infants who are artificially fed rather than breastfed being at increased risk of illness, impairment and death (Allen & Hector, 2005; Cunningham, 1995; Evenhouse & Reilly, 2005; Fildes, 1995). According to Fildes (1988, 1995), infant feeding practices changed rapidly in Western Europe during the 18th century. Traditionally the infants of wealthy families were sent away to be suckled by wet-nurses until weaning, but beginning in the late 17th century, dry-nursing, in which infants were fed a mixture of grains and water, broth or milk, gained in popularity. However, people soon realized that dry-fed infants were more likely to succumb to disease and death than their wet-nursed counterparts and, thus, a movement began among the upper-classes to keeping infants at home, where care and feeding could be closely supervised by the mother. Although dry-nursing lost popularity rather quickly among the elite, who followed the medical advice of the time and either breast fed their own infants or hired live-in wet-nurses, dry-feeding took firm hold among the working poor. Dry-feeding was cheaper than wet-nursing and it allowed working women to return to work within days of giving birth. Dry feeding also allowed unwed mothers to be free of the social stigma of raising an illegitimate child because they were able to send their offspring to a caregiver or, more nefariously, a baby-farmer, who would purport to house, feed and care for the child in exchange for a periodic fee, but would sometimes starve or beat him or her to death and continue to collect the money (Cohen, 1986).

Isotopic evidence from Christ Church, Spitalfields, London, supports a strong relationship between socioeconomic conditions and infant feeding practices during the 18th and 19th centuries (Nitsch et al., 2011). Nitsch et al. found evidence for extended breast feeding among infants buried in the crypts of Christ Church, which, given their expense, contained relatively well-off individuals. Nitrogen isotope levels suggest some infants were nursed until at least 1.5 years of age, more than twice as long as the commonly cited 18th century average of 7–9 months for all of Britain (Fildes, 1995). Socioeconomic differences in infant feeding practices would have resulted in differences in morbidity and mortality between wealthy and poor infants and may also have had lasting effects on those who survived into adulthood. Breast milk triggers the development of the infant's own immune system and provides an external source of immunoglobulins while the infant's defenses are insufficient (Cunningham, 1995), meaning those that were dry-fed would likely have had dampened immune responses. Not only were dry-fed infants likely to be immune compromised, but artificial feeding also put them at increased risk of environmental exposure to pathogens that caused diarrhoeal diseases, respiratory disease, otitis media, urinary tract infections and other infectious diseases, as compared to their breastfed counterparts (Allen & Hector, 2005; Cunningham, 1995). Artificial feeding has also been linked to impaired cognitive ability (Evenhouse & Reilly, 2005), and tentative links have been established between artificial feeding and chronic diseases later in life, such as heart disease and diabetes, and autoimmune diseases, such as Coeliac and Crohn's disease (Allen & Hector, 2005).

The children of the labouring classes would also have been at higher risk of exposure to environmental contaminants and epidemic disease given their living conditions. Industrialization attracted young labourers from the countryside to the city centre, where wages were markedly higher (Hill, 1985; Schofield, 1994; Williamson, 1994). Unfortunately, the number of labourers hoping for high-paying manufacturing jobs far surpassed the demand, and many recent migrants resorted to low-paying jobs in service industries (Williamson, 1994). With nearly 50% of the population of England living in a city by the mid-19th century (Schofield, 1994), urban centres like London were in the midst of a substantial housing shortage. Migrant families were forced to down-size their living quarters in order to bear the burden of skyrocketing housing costs (Williamson, 1994). The result was overcrowding, which leads to the proliferation of epidemic diseases and unsanitary conditions that, in turn, result in high adult and infant mortality (Schofield, 1994; Williamson, 1994). Not only were the living conditions of higher status people better within the City, many of them had properties outside of the city, so they would have spent less of their time exposed to any dangers that did exist in the urban setting. Poor Law Reformers and doctors brought attention to the environmental, preventable, causes of illness and death and public officials began to address the sewage and sanitation issues associated with overcrowding in the mid 1840s, with resultant declines in mortality evident by the 1850s (Hill, 1985). Declines in infant mortality, however, lagged significantly behind, not occurring until the turn of the 20th century (Millward & Bell, 2001).

The relatively small number of children in our high status sample raises the question of whether our results are an artifact of differential preservation or burial treatment leading to a disproportionately small number of high-status children's burials. If this were the case, we should not interpret the relatively small number of children in our high status sample as reflecting a lower risk of mortality. However, there is no reason to expect that the burial of children differed between socioeconomic strata in industrial London in a way that would have resulted in comparatively few high status children's burials. Relatively large numbers of infants and children have been recovered from high status crypt burials at the contemporaneous site of Christ Church Spitalfields (Lewis & Gowland, 2007), suggesting that high status children were being interred in much the same way as adults during this period. The presence of a child buried in a lead coffin at St Bride's Fleet Street (Milne, 1997) shows that not only are children being interred in the high status assemblage, but they are also being afforded the same treatment as adults.

In fact, we expect that under-representation of children poses more of a potential problem for the lower status sample rather than the high status sample. In St Bride's Lower Churchyard, Farringdon and in other low status cemeteries from this period, because of space constraints, coffins were stacked on top of each other (up to 10 high) in large pits. These large burial pits were kept open until filled and burials at the top of such pits tended, during this period, to be reserved for infants and children (Brickley & Miles, 1999). Being closest to the surface, burials of low status children might have been disproportionately destroyed by subsequent rebuilding or wartime bombing. Further, it was not uncommon for the church to charge a baptism fee and a parish register fee (Ambler, 1987) in order to complete the baptism right, and burial in the churchyard came with an additional fee, depending on the size of the grave (Sayer, 2011). These fees could have resulted in fewer indigent children's burials than expected, as unbaptized children were not permitted burial in the churchyard (Ambler, 1987; Sayer, 2011) and the cost of burial, had one been baptized, may still have been prohibitive. Children were also sometimes buried with unrelated adults. If children are under-represented in our low status sample, the mortality and survival differential between high and low status children would have been even stronger than we estimated.

The London Bills of Mortality (which provide totals of baptisms and burials from London parishes, with burials-by-age data available beginning in 1728) can provide comparative historical data for our samples. In the late 17th–early 19th century in London infant deaths (those occurring in first year of life) generally made up over 30% of deaths in London parishes (Landers, 1987; Razzell, 1994), a proportion much larger than what we find in our samples, indicating that we do not have a representative sample of young children from these cemeteries. This is apparent in both the high and low status assemblages, although differences between these samples with respect to the extent of infant and child under-enumeration cannot be determined from the available data. However, even if the estimated mortality and survival differentials between the high and low status sub-adults reflects sample bias only and, thus, does not reflect a real differences in the living population, the fact remains that we failed to observe a difference in mortality and survival when analyses were restricted to adults. The surprising result indicating no substantial difference in mortality or survival between high and low status adults requires explanation. One possible explanation for this finding is that selective mortality operated during childhood and led to declines in mortality and survival differentials with age. The possibility of selective mortality removing the frailest low status children is important to consider, regardless of whether we can say with absolute certainty that our analyses reveal a real difference in mortality or survival between low and high status children.

It has been suggested, however, that socioeconomic status may have had little net impact on childhood mortality or mortality in any age group during this particular time period (Razzell, 2005; Razzell & Spence, 2005). If this is indeed the case, then we must consider alternative explanations for the reduced socioeconomic-status differentials in mortality among adults uncovered in our analyses and look more closely at the population dynamics of the 18th and 19th centuries.

There was a high rate of migration into London during this time period. We have biographical information for several individuals interred in the St Bride's Fleet Street crypt that makes it clear that they came to London as adults. The same was likely true for many individuals in all the assemblages used in this study (Porter, 1982). As rural economies flagged and industrialization took hold in large cities throughout England, London in particular saw an influx of migrants seeking economic opportunity. It is evident that the size of the young-adult population of London exceeded the national average (Davenport et al., 2010) and that there was a corresponding decrease in the young-adult population in rural areas, as cities increased their share, resulting in decreasing dependency ratios in urban settings (Williamson, 1988). The new economy of London was, therefore, attracting primarily young-adults. This raises the possibility that the reduced socioeconomic-status differentials in mortality among adults in our samples result from the inclusion of migrants into the City. The possibility of migration affecting our estimates, however, presumes that immigrants would have been relatively healthy and capable of maintaining that good health following immigration, as compared to native-born Londoners, perhaps because they avoided the potentially damaging effects associated with an urban environment during childhood or because healthier individuals are more likely to migrate. Unfortunately historical documents prior to the 1821 census do not regularly provide place-of-birth information, making it difficult to compare the two cohorts directly, although there is some evidence to suggest migrants may have been relatively healthy.

While it has been argued that new migrants may be more vulnerable than members of the native population, due to immunological naiveté, and, therefore, more likely to succumb to disease and death (Landers, 1987; McNeill, 1980), that was not necessarily the case for industrializing London. Migration may have been selective, in that young-adults in good health were more likely to migrate than children, older adults and unhealthy individuals (Davenport et al., 2010; Humphries & Leunig, 2009; Williamson, 1988). Humphries & Leunig (2009) analysed the 1844–1848 'Register of Seamen's Tickets' from the Admiralty and Board of Trade's General Registry and Record Office and found that male merchant seamen who chose to migrate to London were, on average, taller than those who did not choose to migrate. The authors, working on the assumption that taller individuals are healthier and have greater opportunities in life, assert that London was, therefore, attracting relatively healthy migrants who would have had opportunities elsewhere. Davenport et al. (2010) analysed burial records from London's St Martin in the Fields (1750–1824) and also concluded that young-adult migrants were relatively healthy, as they were no more likely to die from smallpox than the general population and may have been less likely succumb to tuberculosis, which was probably already endemic in the rural areas from which the migrants were drawn. Further, while a pronounced 'trauma hump' of excess young-adult mortality is evident in the national data for England during this time period, it is absent in the young-adult cohort (which would have contained most migrants) of St Martin in the Fields in the 19th-century, suggesting a comparative advantage over the national population. This is not altogether surprising, as the trauma hump has been shown to be context-specific, rather than universal (Gage & Dyke, 1986), and particularly responsive to economic cycles, often disappearing completely when economic opportunities for young-adults abound (Reichmuth & Sarferaz, 2008).

This may seem to be in stark contrast to London's reputation as bleak, squalid and sickly, but nearly 60% of the growth of English cities between 1776 and 1811 was due to immigration (Williamson, 1988), meaning England's cities were more economically attractive than prospects in rural areas. Early in industrialization, when the need for labourers was greatest, this may have improved the life circumstances of those who moved to London, resulting in declining mortality. Williamson (1988) notes a steady decline in mortality throughout early industrialization and Davenport et al. (2010) note a proportional decline in the number of pauper burials relative to non-pauper burials during this time period, suggesting the decline in mortality may have disproportionately benefitted the lower social strata. As mortality decreased, however, the inverse would be true of the rate of natural increase, reducing the need for migrant labour, although not necessarily its supply. The censuses of 1821–1851 capture the decline in the relative importance of migrant labour, as they demonstrate a reduction in the young-adult excess evident in previous decades (Williamson, 1988). Szreter & Woolcock (2004) note that, between 1820–1870, living conditions in cities began to deteriorate and life expectancies fell, concomitant with the appearance of disparities in mortality between the wealthy and the poor, according to Razzell & Spence (2005), beginning with a decline in infant mortality among the wealthy in the mid-19th century.

Together these studies suggest that migrants were at least as healthy as, if not healthier than, the native-born population of London in this time period. If this was the case, our results could potentially be evidence of migrant selectivity operating in London during industrialization. Isotopic analysis may prove useful in identifying migrants and, thereby, allow direct comparison of migrants to native-born Londoners; however, such analyses have not yet been carried out and are beyond the scope of the present paper.

It is also possible that there was disproportionate migration out of the city among the wealthier classes and if this occurred primarily in older adults it might have skewed the age distribution sufficiently that our results partly reflect the effects of migration. In particular, if there was higher migration of wealthy individuals out of the city at older ages, the effect would have been to reduce the number of older adults in the high socioeconomic status skeletal sample such that the risk of death for high status adults, in general, was over-estimated in our study. This might explain, at least in part, why there was a lack of a status differential in mortality for the adults in our samples. That is, instead of or in addition to strong selective mortality weeding out the frailest of the low status individuals during childhood, it is possible that the wealthiest and, thus, potentially the least frail individuals left the city at older ages and did not enter our skeletal samples. If these individuals had remained in the city and, thus, were included in our samples, we might have observed a continuation of the difference in risk of death between high and low status individuals into adulthood.

If outmigration occurred in such a way, we should see a higher proportion of older adults in the Chelsea Old Church cemetery compared to the St Bride's Fleet Street assemblage, as the former was located in what was, at that time, a more rural area. The age-at-death distributions of the two high status cemeteries are, in fact, significantly different (Kolmogorov-Smirnov, $p < 0.05$); however, there are more adults above the age of 50 in the *urban*, rather than the rural, sample. We also examined survival differentials between the two high status assemblages and Kaplan Meier survival analysis reveals significantly higher survival in the urban setting (Mantel Cox, $p < 0.001$). The results might indicate that St Bride's Fleet Street was considered a more prestigious burial site and, thus, more of a draw for influential and well-to-do individuals than the parish churchyard of Chelsea Old Church (Thornbury, 1986). Importantly, the results do not indicate enhanced survival at advanced ages in the rural setting, which is what we would expect if large numbers of older high status adults migrated to the countryside from the city. Historical evidence from early in the period suggests that high status households were somewhat more stable than low status households, in that they had lower residential mobility and those that did move were likely to move within their home district (Boulton, 1987). Further, family histories for known individuals and the presence of children in family burial plots at Chelsea Old Church, suggest prominent members of Chelsea society were raised and came to raise their own children in Chelsea rather than retiring there (Cowie et al., 2008).

It is possible that the interval age-estimates and particularly the open terminal age category 46+ have resulted in an under-estimation of the differences between high and low status adults. However, a recent analysis of mortality differences between monastic and non-monastic communities in London (1050–1540) used these same age categories and sample sizes comparable to those used in our study (DeWitte et al., 2013). That study found a substantial difference in adult mortality between the monastic and non-monastic communities using a hazards approach like that used here. Thus, it is possible to find differences in adult mortality using these age estimates. Although we do see variation in the adult age-at-death distributions between the two status groups, we are not able to recognize variation in age-at-death beyond the age of 46. This can be resolved by using more accurate age estimation methods; but analysis of those data is beyond the scope of the current paper. It should also be noted that we only have estimates for the majority of our sample of the age at which individuals died during the period the relevant cemetery was in use, but we do not know their dates of birth or death. Thus, we are necessarily pooling different cohorts and we face the possibility that by doing so we might have failed to detect demographic differences or that those differences we do observe might reflect temporal variation instead of, or in addition to, true differences between high and low status individuals at any one particular point in time.

While this is certainly a limitation of our data, demographic studies from other regions of industrializing Europe have also failed to find convincing evidence of an association between socioeconomic status and mortality among adults during this time period (Bengtsson & Dribe, 2011; Bengtsson & van Poppel, 2011; Breschi et al., 2011; Edvinsson & Lindkvist, 2011; Gagnon et al., 2011; Schenk & van Poppel, 2011). Further, it has been suggested that social gradients in adult mortality health are not found among the oldest adults, rather they are exclusive to working-aged adults (Antonovsky, 1967; Bengtsson & Dribe, 2011; Bengtsson & van Poppel, 2011; Schenk & van Poppel, 2011). Ideally we would be able to confirm this phenomenon in our sample but, in the absence of more accurate age estimates (an approach presently being taken by one of the authors), that is beyond the scope of the current paper. We are, however, looking at precisely the age groups in which one would expect to see the greatest effects of socioeconomic status on mortality, if there were indeed such health disparities.

Changes in socioeconomic mortality disparities with age have been found in studies of living populations (most of which are Westernized and industrialized). Many studies that have explicitly examined whether socioeconomic differentials in health or mortality are uniform across age have found that socioeconomic differences in health or mortality decrease with increasing age, supporting the ''age-as-leveller'' hypothesis (Dupre, 2007). For example, Martikainen et al. (2001) found that, in Finland in the 1990s, mortality and income were strongly linearly associated for ages below 64 years, but the strength of the association declined rapidly at later ages. Such convergences at later ages are often interpreted as reflecting mortality selection at younger ages (Beckett, 2000; Hoffmann, 2005). Beckett (2000), however, suggests that the convergence of health differentials in the US in the 1980s might have occurred because of postponement of morbidity to late adult ages among higher socioeconomic status individuals. This pattern of declining differentials with age is not universal, however; for example, Huisman et al. (2004) found that, in 11 European countries in the 1990s, socioeconomic differences in mortality persisted at late adult ages and in some cases the magnitude of the difference at late ages was similar to that for middle-aged adults. Marmot & Shipley (1996) found that, among British civil servants, the magnitude of mortality differentials actually increased with age after retirement. Nonetheless, the results of our study and several done in living populations suggest that the phenomenon of selective mortality reducing socioeconomic differentials at late ages can occur under a variety of diseases, healthcare and political-economic conditions and are likely not characteristic only of modern, industrialized populations that have undergone the epidemiological transition.

Conclusion

The results of this study indicate a surprising lack of a mortality or survival differential between high and low status adults in industrial-era London. The lack of a significant effect of socioeconomic status on adult mortality and survival might reflect reduced chances of survival for low socioeconomic status children in early modern London and that the effects of selective mortality at younger ages had important consequences for heterogeneous frailty among adults in this population, as has been suggested for living populations (Hoffmann, 2005). These results might also reflect the effects of migration into London during this period. These are not mutually exclusive possibilities. The pattern found here could result from a combination of both reduced chances for survival among low socioeconomic children and the influx of healthy young-adult migrants into the City. This study not only adds to our understanding of variation in health and mortality in early-modern London, but also serves as a reminder that reconstructing such patterns from skeletal material requires us to recognize that these patterns may vary by age and across sub-populations.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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