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Socioeconomic status and survival in medieval Canterbury

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ABSTRACT

The adverse urban environment of medieval Canterbury possibly influenced poor health conditions and diseases which ultimately led to death. Individuals of low socioeconomic status may have been more at risk of death than those of higher socioeconomic status due to dense living conditions, consistently encountering unhygienic waste management, and less access to resources during famines and disease outbreaks. This study evaluates survivorship and mortality risk patterns of high- and low-status groups to determine the effect of socioeconomic status on survival and mortality in medieval Canterbury. A sample of 796 low- and 74 high-status individuals were examined from St. Gregory's Priory. Kaplan-Meier analysis and Cox Regression were used to assess mortality and survival between the socioeconomic status groups. The results reveal lower survivorship for high-status than low-status non-adults, and lower survivorship and high mortality risk for high-status adult females compared to low-status adult males. Meanwhile there were no significant differences found in mortality risks and survivorship between low- and high-status adult males, low- and high-status adult females, and low-status adult females and high-status adult males. High risk of mortality and decreased survivorship of high-status adult females may reflect decreased survivorship of high-status non-adults due to poor nutritional intake during and after pregnancy as well as rationing food. In comparison, low-status adult males would have benefited from the pilgrimage culture that allowed them abundant access to nutritious foods.

1. Introduction

Socioeconomic status (SES) is used in bioarchaeological studies to recognise potential health inequities in past societies. Studies often use age-at-death distributions to identify mortality patterns of SES groups (Cook, 1981; Grauer, 1989; Miszkiewicz, 2015; Powell, 1988; Sullivan, 2005, 2004). However, age-at-death distributions do not measure the relationship between mortality patterns of multiple groups (Wilson, 2014). This relationship is commonly identified through studies of survivorship (probability of surviving) and/or mortality risk (risk of dying) patterns (Betsinger et al., 2020; Boldsen, 2007; Dewitte et al., 2013; Godde et al., 2020; Kelmelis and Dangvard Pedersen, 2019; Redfern et al., 2015; Redfern and Dewitte, 2011; Wilson, 2014). Many studies of survivorship and mortality risk patterns in England predominantly focus on London (DeWitte, 2017, 2015, 2014, 2010; Dewitte et al., 2013; DeWitte et al., 2015; Godde et al., 2020; Godde and Hens, 2021; Yaussy et al., 2016; Yaussy and DeWitte, 2018) which leads to less understanding of other areas in England.

Canterbury was a prominent sacred place for theology from the 11th to 15th centuries. It was delegated the southern province of England for the Roman Catholic Church during the medieval period (Clegg, 2003). Churches in Canterbury established shrines for saints to encourage pilgrimages (Clegg, 2003; Lyle, 2002). Saints were revered for their heroic acts and commitment to Christianity (Hopper, 2002; Lincoln, 1955; Lyle, 2002; Martin, 1950). Pilgrims frequently visited the shrines to provide donations in exchange for receiving miracles and indulgences, also known as the pilgrimage culture (Ekelund et al., 1996; Hopper, 2002; Sorabella, 2011). Additionally, pilgrims would donate monetary funds to hospitals and beggars along their journey (Hopper, 2002; Lyle, 2002; Webb, 2000). The pilgrimage culture encouraged people to migrate to Canterbury to start businesses to provide lodgings, food and drink, and souvenirs for pilgrims (Hopper, 2002). By AD 1200, Canterbury was well populated, influencing dense housing conditions and unhygienic waste management (Lyle, 2002). These conditions, in addition to adverse weather, encouraged the spread of infectious diseases (Rawcliffe, 2013). Furthermore, adverse weather affected food supply leading to sporadic famines resulting in people developing nutritional deficiencies (Rubin, 1974). Previous anthropological studies on medieval Canterbury have focused on health between SES groups. However, less is known about the effects of medieval Canterbury's urban

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environment on individuals' survivorship and mortality risk patterns. Therefore, this study looks at survivorship and mortality risk of high and low status adults and non-adults from medieval Canterbury.

1.1. Anthropological studies of survivorship and mortality patterns

Previous studies compare rural and urban areas (Redfern et al., 2015; Walter and Dewitte, 2017), pre-, post-, and during black death periods (DeWitte, 2017, 2015, 2014; Godde et al., 2020), famine and non-famine periods (Yaussy et al., 2016; Yaussy and DeWitte, 2018), and individuals with osteological stress markers (DeWitte, 2010; Godde et al., 2020; Godde and Hens, 2021) in terms of survivorship and mortality patterns. Walter and DeWitte (2017) found that adults from urban medieval London had a higher risk of mortality and decreased survivorship compared to rural Barton-upon-Humber, Lincolnshire. Also, urban females were more at risk of dying earlier and had a decreased survivorship compared to urban males and rural males and females (Walter and Dewitte, 2017). They suggest the urban environment was more detrimental to health than the rural environment (Walter and Dewitte, 2017). Additionally, young women migrants to London were potentially vulnerable and suffered from poverty, famine, and increased exposure to pathogens (Walter and Dewitte, 2017).

Medieval English urban environments were hazardous to people's health. Housing was closely compacted, and populations were dense, which exposed people to various infectious diseases, nutritional deficiencies, and high parasites loads (Rawcliffe, 2013). Godde and Hens (2021) found that all SES groups (high, middle, low, and monks) and males and females with cribra orbitalia had a similar risk of mortality in medieval London. They suggest parasites would have been transmitted equally in all SES groups, and females would have suffered from iron and vitamin D intake due to poor diets while males were more susceptible to infections by parasites (Godde and Hens, 2021). Studies have found that before the Black Death, individuals had low survivorship and high mortality risk in medieval London (DeWitte, 2017, 2015). DeWitte (2017, 2015) suggests that the overall health of people in London deteriorated in the 13th century, which might have led to high mortality patterns during the Black Death. DeWitte (2010) noticed that during the Black Death in London, males with multiple osteological stress markers had an increased risk of mortality compared to females and suggests that the modern pattern of female longevity was also similar in the past. Additionally, Godde and colleagues (2020) found that individuals with one or more osteological stress marker had a 1.67-fold increase hazard for dying of the Black Death compared to those without stress markers. They suggest that mortality was selective towards individuals whose health was compromised due to early life adverse exposures (Godde et al., 2020).

The food quality and supply were often insufficient in urban areas, especially during times of famine (Rawcliffe, 2013; Pribyl, 2017). Yaussy and colleagues (2016) found, prior to the Black Death in London, no significant difference between mortality risks of males and females during famine and non-famine periods. However, they identified that after the Black Death, males had a lower risk of mortality during non-famine periods (Yaussy et al., 2016). They suggest two potential causes: living conditions and diets improved which increased individuals' chances of surviving the Black Death, or the Black Death strongly targeted individuals who were frailer (Yaussy et al., 2016). These studies provide significant information about the influence that medieval London's urban environment had on survivorship and mortality risk patterns. However, studies on other urban areas in England would identify similarities and/or differences of the urban environment on mortality and survivorship across the country.

1.2. Socioeconomic status in medieval England

The social hierarchy structure during medieval England primarily consisted of high- and low- status groups. Those of high-status consisted of royalty and aristocrats, such as earls, barons, lords, etc., and clergy members, including those in monastic orders (Dyer, 1989). In medieval Canterbury, the archbishops were the earls which placed them at a higher position compared to other clergy members in the English society (Lincoln, 1955). Lower status individuals were typically merchants, craftsmen, servants, agricultural workers, and beggars (Dyer, 1989).

High-status individuals lived in large residences such as castles, manors, cathedrals, or monasteries with individual spaces for sleeping, cooking, storage for food and drinks, and training and breeding horses (Dyer, 1989). These large domestic establishments were often venues for administrative duties and meetings for estate, council members, or diocesan officials (Dyer, 1989). Large homes within or near the city's wall were also rented for conducting business and family outings (Dyer, 1989; Lyle, 2002). Those of low-status lived in midsized or small households, hospitals, or almshouses (Leyser, 1995; Roberts and Cox, 2003). Midsized households consisted of two to four storey homes that had separate spaces for cooking and sleeping for the family and servants (Dyer, 2000, 1989; Roberts and Cox, 2003). Business owners would have had their shops on the first floor and their living quarters in the floors above (Roberts and Cox, 2003). Small households are defined as one storey homes that had one or two rooms for cooking, sleeping, and a living space shared with multiple family members and few servants (Dyer, 2002, 1989). These homes tended to be located in the southern quarter, both within and outside of the city's walls (Lyle, 2002). Hospital patients and almshouses residents lived in small to semi-large establishments organised by monasteries (Orme and Webster, 1995). Travellers, pilgrims, beggars, those who were disabled, and people who were ill resided in hospitals temporarily or permanently (Magilton, 2008a; Orme and Webster, 1995). Hospitals would occasionally turn away people who were terminal or infectious (Orme and Webster, 1995). For example, people who were thought to have had leprosy were admitted into hospitals specific to leprosy known as a *Leprosariums* (Magilton, 2008b; Orme and Webster, 1995). Elderly without means of support from family and people who were not financially stable tended to live in almshouses (Prescott, 1992).

Hospitals and almshouses received income from donations to assist with the care of people who lived there (Orme and Webster, 1995; Prescott, 1992). Those who lived in small households gained earnings from their occupation such as crafting, innkeeping, brewing, tanning, butchering, fishing, or in the construction, food, drink, and cloth industries (Dyer, 2002; Hazell, 2007; Miller and Hatcher, 1995). For high-status individuals, collecting taxes, land grants, and tenancies were their primary sources of income (Dyer, 2002). Within cathedrals and monasteries, administrative tasks were predominantly conducted by men (Clegg, 2003; Ward, 2006). In manorial residences, women sometimes took part in the administration of the house and estates especially in the absence of their husbands (Leyser, 1995). Married low-status women would often assist with their husband's trade, for example by becoming an embroiderer or silkwoman for a tailor or brewsters for inns and taverns (Hanawalt, 2007). Low-status children and single women were more likely to work as labourers and servants (Lewis, 2016; Leyser, 1995). High-status children were sent to monasteries and nunneries for upbringing and education (De Jong, 1996; Gransden, 1972).

The budgets of high-status individuals were primarily spent on food and drink (Dyer, 1989). Large quantities of ale, wine, meat, and fish were brought routinely and served for meals (Dyer, 1989). They regularly stocked or purchased a supply of fresh meat from butchers (Dyer, 1989). High-status people maintained large gardens, more for food production and less for their own consumption (Dyer, 2006). Those of lower status had gardens and yards with livestock for producing wool, dairy products, and meat (Dyer, 2002). Their food consisted of bread, a stew of grains and vegetables, fruits, ale, and a limited supply of meat and cheese (Dyer, 1989; Roberts and Cox, 2003).

1.3. Anthropological studies of SES in medieval Canterbury

1.3.1. Adults

Studies have found differences between high- and low-status adults in bone health, diet, and childhood stress frequencies (Miszkiewicz, 2015; Miszkiewicz et al., 2019; Walker et al., 2019). Miszkiewicz and colleagues (2019) found that high-status individuals developed higher osteon population density in their femurs and an associated higher protein diet compared to low status individuals. Miszkiewicz (2015) found that low-status individuals, compared to high-status, had a higher frequency of linear enamel hypoplasia. It is suggested that their health was more heavily disrupted during childhood compared to those from priory (Miszkiewicz, 2015). Walker and colleagues (2019) found that an increase in linear enamel hypoplasia is associated with an increase in osteon population density in individuals from high SES backgrounds. They suggest that childhood physiological stress predisposed the skeleton to become robust in adulthood for the high SES group (Walker et al., 2019). However, low SES individuals did not show a relationship between linear enamel hypoplasia and osteon population density (Walker et al., 2019). It is suggested that physiological stress caused poor bone health in adulthood for low-status adults (Walker et al., 2019).

1.3.2. Non-adults

Studies have found differences between infancy stress and physical activity of high- and low-status non-adults (Miszkiewicz et al., 2019; Pitfield et al., 2019). Miszkiewicz and colleagues (2019) found that between 2 and 8 months of age, high-status children had a higher prevalence of dental accentuated markings on the first permanent molars and second deciduous molars compared to low-status children during infancy. They suggest this period of stress is the infant immune response to mixed-feeding between breastmilk and soft foods and was greater for higher status groups compared to lower status groups (Miszkiewicz et al., 2019). Pitfield and colleagues (2019) found that low-status 8- to 12-year olds had smaller osteon area and osteon diameter and less circular osteons in the humerus than high-status older children. Thus, they suggest low-status older children participated in more physical activities compared to high-status older children (Pitfield et al., 2019).

1.4. Hypotheses

These studies of SES in medieval Canterbury suggest that high-status adults had better health compared to low-status adults. In contrast, these studies suggest that low-status children had an overall good health compared to high-status children. Therefore, this study tests the hypotheses that adults of high-status had an increased survivorship and lower mortality risk compared to low-status adults, and that non-adults of low-status had lower mortality risk and increased survivorship compared to high-status non-adults.

2. Materials and methods

St. Gregory's church was founded by Archbishop Lanfranc in AD c.1084 as a sister establishment to St. John's Hospital (Cowdrey, 2003; Hicks and Hicks, 2001; Hicks, 1989; Orme and Webster, 1995; Sparks, 2001). It was a community of six priests and twelve clerks who heard confessions, performed baptisms, ministered to sick individuals, and provided burial services (Cowdrey, 2003; Hicks and Hicks, 2001; Hicks, 1989; Rubin, 1974; Sparks, 2001; Tatton-Brown, 1995). In AD 1133, Augustinian cannons, implemented by Archbishop William of Corbeil, replaced Lanfranc's clergy and transformed St. Gregory's into a priory (Hicks and Hicks, 2001; Hicks, 1989; Sparks, 2001). St. Gregory's Priory consistently interacted with the archbishop of Canterbury (Hicks, 1989). It kept the treasury and archives of the archbishop and important diocesan records, accommodated important guests of the archbishop, and held some sessions of the archbishop's consistory court (Hicks, 1989; Tatton-Brown, 1995). St. Gregory's provided burial services free of charge within the cemetery (Hicks and Hicks, 2001; Sparks, 2001; Tatton-Brown, 1995). Additionally, the cemetery provided burials for St. John's Hospital, St. Mary's parish and other parishes in Canterbury until the late 16th century (Sparks, 2001; Tatton-Brown, 1995).

Canterbury Archaeological Trust uncovered the building complex of St. Gregory's church and later priory as well as an associated cemetery in 1988 (Anderson, 1989; Anderson et al., 1990a; Bennett, 1988). The cemetery was completely excavated in 1989 (Houliston, 1989). The graveyard seems to have been in use from at least the late 11th century until the dissolution of the Priory in 1537 (Anderson et al., 1990b). A total of 1,342 articulated skeletons were excavated from the cemetery, church and later priory (Anderson and Andrews, 2001). Approximately, 91 graves were associated with the church and priory (Anderson and Andrews, 2001).

Previous studies on SES in medieval Canterbury have analysed individuals from St. Gregory's Priory skeletal collection because of the burial nature of SES groups (Miszkiewicz, 2015; Miszkiewicz et al., 2019; Pitfield et al., 2019; Walker et al., 2019). As mentioned in Lanfranc's obituary, the clergy members were to provide burial for the poor without charge in the cemetery (Hicks and Hicks, 2001; Sparks, 2001; Tatton-Brown, 1995), which indicates that low-status people were buried there. It is suggested that high-status people were buried in the church and later priory due to the associated grave goods such as a pewter chalice, gold thread, and pottery fragments, historical records of bodies of saints being held in the church, and wills of people requesting to be buried within the priory (Hicks and Hicks, 2001; Hicks, 1989). Hence, those who were buried in the cemetery are classified as low-status individuals and those who were in the priory are classified as high-status individuals for this research. This study analysed 545 low- and 47 high-status ($n = 592$) adults and 251 low- and 27 high-status ($n = 278$) non-adults from St. Gregory's Priory (Table 1).

Age-at-death of non-adults and biological sex and age-at-death of adults were reconstructed for analysis. Adult age-at-death was estimated using Boldsen and colleagues (2002) transition analysis method. The scoring method for the morphological age characteristic changes of the auricular area, pubic symphysis, and cranial sutures (Boldsen et al., 2002) were used for this research. Individuals with one or all of the skeletal elements preserved were analysed. The scores were collected and placed into the Anthropological Database, Odense University (ADBOU 2.1) age estimation software. The ADBOU 2.1 produces lower 95 %, maximum likelihood, and upper 95 % age estimation probabilities. This study used the maximum likelihood estimates ages-at-death. Chamberlain (2006) defined the last maturational stage to end at 17 years; therefore, in this study adults were classified as 18 years and older and non-adults as 17 years and younger. Non-adult age-at-death was estimated using the dental development and eruption stages of the London Dental Atlas (AlQahtani et al., 2010) and the long bone length linear regression formulae (Primeau et al., 2015; Scheuer et al., 1980). The median age-at-death was calculated from the age ranges given to non-adults. Individuals were not placed into age categories due to the nature of the statistical methods used in this study. Biological sex of adults was assessed using Klales and colleagues (2012) pubic bone characteristics formulae and Buikstra and Ubelaker (1994) scoring methods of the greater sciatic notch, nuchal crest, mastoid process, supra-orbital margin, glabella, and mental eminence. Non-adults were not assessed for biological sex due to the difficulty of identifying it across

Table 1
Distribution of high-status and low-status adults and non-adults.

		High-Status	Low-Status
Adults	Males	30	262
	Females	17	283
Non-adults		27	251

all childhood ages as well as the variation in the development of biological sex traits among individuals. Therefore, non-adults and adults were examined separately.

Two statistical methods were used for analysis: Kaplan-Meier and Cox Regression. Kaplan-Meier was used to explore the survival patterns of high and low status groups and to test the overall survival between the groups. Cox regression was used to identify the effect estimate (estimate of the size difference between the groups) to compare the mortality patterns of high- and low-status groups. Both the Kaplan-Meier and Cox Regression require continuous (time/duration) and categorical (event and covariates) variables (Benítez-Parejo et al., 2011; Ranstam and Cook, 2017). For this study, age-at-death was the continuous variables and death, SES, and biological sex were the categorical variables. The Kaplan-Meier method is a non-parametric test that does not require a normal distribution of data (Cantor and Shuster, 1992). It consists of a survival curve and log rank test. Age-at-death was used for the time variable, death (coded as 1) was the status of the individuals, and SES and adult biological sex were the factors. The survival curve calculates the cumulative survival and plots it against the age-at-death estimates of adults and non-adults. The log rank test compares the survival patterns of the SES groups to identify statistical significance. The Cox Regression a is semi-parametric test that does not require the distribution of data to have strong assumptions and only the proportional hazards are made up of assumptions (Heitfield and Levy, 2001; Paoletti and Asselain, 2010). It calculates the hazard of dying between the SES groups. Age-at-death was used for the time variable, death (coded as 1) was the status of individuals, and the covariates were SES and biological sex of adults. Six tests were conducted for each statistical method: high- compared to low-status adults, high- compared to low-status adult males, high- compared to low-status adult females, high-status adult males compared to low-status adult females, high-status adult females compared to low-status adult males, and high- compared to low-status nonadults. The reference groups for each Cox Regression test are high-status individuals. Additionally, variance inflation factor (VIF) tests were conducted to recognise if the coefficients and p-values in the Cox Regression output are reliable. All statistical analyses were conducted using SPSS 25.

2.1. Fertility proxy

Age-at-death distributions have a stronger association with fertility patterns than mortality patterns (Sattenspiel and Harpending, 1983). This study controls for fertility by using the D_{30+}/D_{5+} method, as it has a robust negative relationship with birth rate, described by Buikstra and colleagues (1986). The D_{30+}/D_{5+} method is the number of individuals above the age of 30 years divided by the number of individuals above the age of 5 and a calculated 95 % comparison interval. The 95 % comparison intervals indicates whether birth rates differed significantly between the groups (Buikstra et al., 1986). The use of this fertility proxy determines whether differences in the survivorship and mortality patterns of the high- and low-status groups may reflect variation in the groups' fertility patterns.

3. Results

3.1. Adults

The survival curve (Fig. 1) shows a slightly higher survivorship for low-status individuals until late 40s when survivorship becomes similar to the high-status group and then decrease around 50 years. The survival curve (Fig. 2) shows high-status males survivorship increased in the early 20s then decreased until late 40s in which it increased again compared to low-status males. Low-status females' survivorship was higher until 30s in which it lowered compared to high-status females and then has similar survivorship to high-status females. Low-status males had higher survivorship compared to high-status females. High-status males had higher survivorship in early 20s then lower in late 20s/early 30s in which it became higher again compared to low-status females.

However, the log rank test (Table 2) shows no statistical significance between low- and high-status individuals, high- and low-status males, high- and low-status females, and high-status males and low-status females. Although, it reveals a significant difference between survivorship of high-status females and low-status males. The results of the Cox regression are shown in Table 3. The p-value reveals a significant difference between low-status males and high-status females in risk of mortality. High-status females had a 41 % reduced hazard of mortality

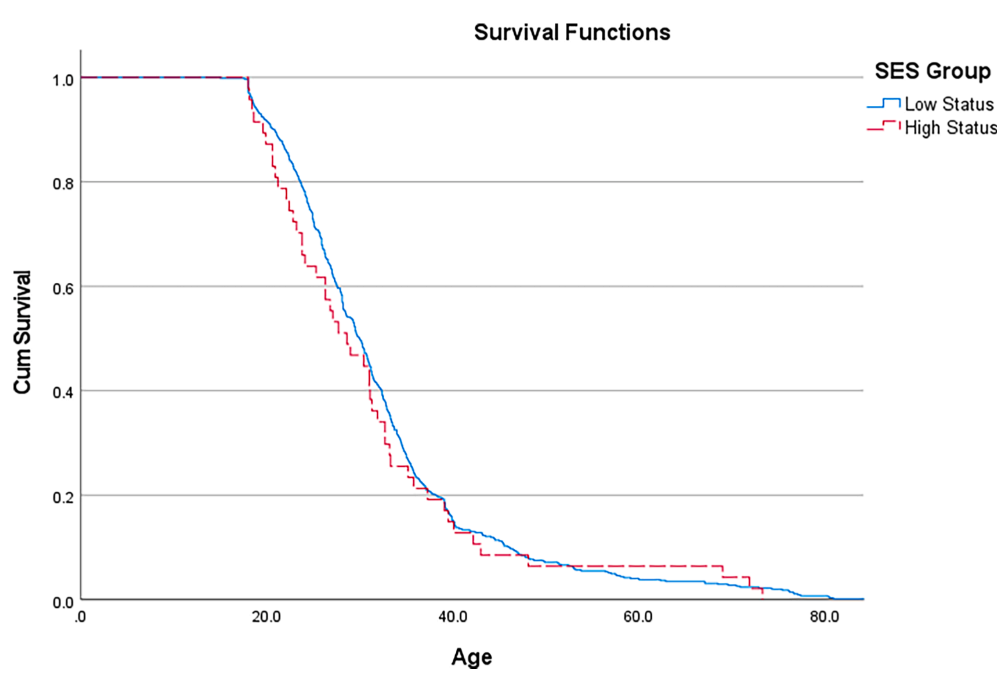

Fig. 1. Kaplan-Meier survival curve of high- and low-status adults.

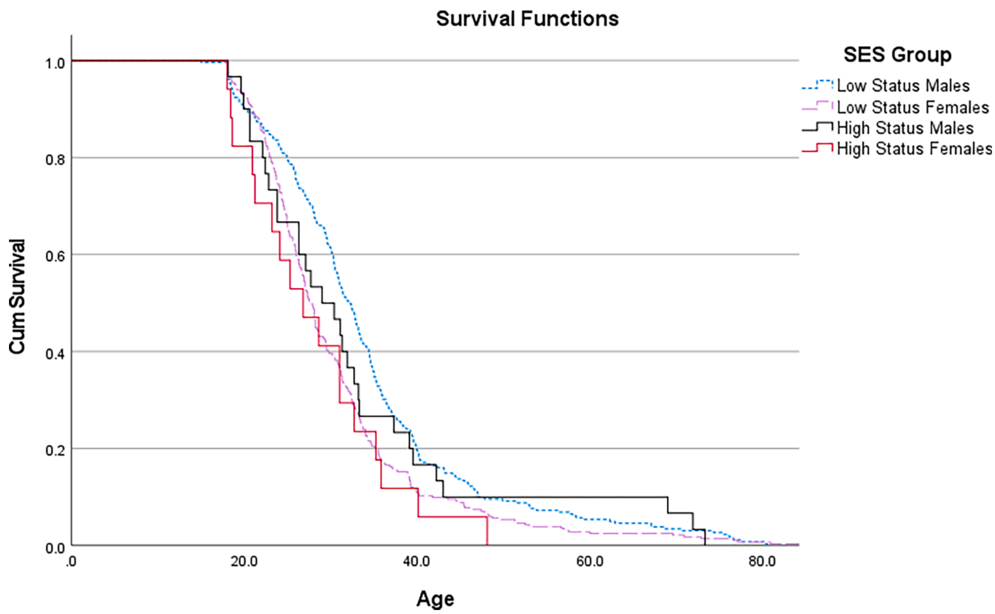

Fig. 2. Kaplan-Meier survival curve of high- and low-status adult males and females.

Table 2
Log Rank (Mantel-Cox) test of high- and low-status adults.

Factors	X^2	df	P-value
High- × Low-Status Adults	0.504	1	0.478
High- × Low-Status Males	0.566	1	0.452
High- × Low-Status Females	0.485	1	0.486
High-Status Males × Low-Status Females	0.695	1	0.405
High-Status Females × Low-Status Males	4.140	1	0.042[1]

[1] Significant.

Table 3
Cox regression analysis of high- and low-status adults.

Covariates	B	Exp (SE B)	df	P-value	Hazard ratio (95 % CI)	VIF
High- × Low-Status Adults	−0.108	0.152	1	0.480	0.898 (0.666–1.210)	1.000[2]
High- × Low-Status Males	−0.145	0.194	1	0.454	0.865 (0.592–1.264)	1.000[2]
High- × Low-Status Females	−0.173	0.250	1	0.489	0.841 (0.515–1.374)	1.000[2]
High-Status Males × Low-Status Females	0.160	0.193	1	0.408	1.173 (0.804–1.712)	1.000[2]
High-Status Females × Low-Status Males	−0.527	0.252	1	0.036[1]	0.590 (0.360–0.966)	1.000[2]

[1] Significant.
[2] No correlation.

compared to low-status males. Which suggests that low-status males had a lower risk of mortality compared to high-status females. The variance inflation factors indicates that the coefficients and p-values of the Cox regression are reliable.

3.2. Non-adults

The Kaplan-Meier survival curve (Fig. 3) shows higher survivorship of low-status nonadults compared to those of high-status. The log rank test (Table 4) reveals there is a significant difference in survivorship between high- and low-status non-adults. The p-value of 0.047 is close to 0.05, which may indicate that the difference is only minor. The results of the Cox regression are shown in Table 5. The p-value suggests there is no significant difference in the risk of mortality between those of high- and low-status non-adults. The variance inflation factor indicates that the coefficient and p value of the Cox regression is reliable.

3.3. Fertility proxy

The fertility proxies and their 95 % comparison intervals for the low- and high-status groups are outlined in Table 6. The D_{30+}/D_{5+} value for the low-status group is higher than the high-status group. This suggests that the birth rates were possibly lower for the low-status group compared to the high-status group. However, the comparison intervals for both groups overlap, which indicates no significant difference between the groups birth rates.

4. Discussion

As a result of the lack of significant differences between the low-status and high-status birth rates, confirmed by the fertility proxies, the survivorship and mortality patterns are recognisable between the groups. These results suggest the first hypothesis that adults of high-status had an increased survivorship and lower mortality risk compared to low-status adults is not supported. The results do, however, supports that non-adults of low-status had an increased survivorship compared to high-status non-adults. The survival patterns of high- and low-status non-adults show a significant difference. Specifically, low-status non-adults had an increased survivorship compared to high-status non-adults until around 14 years of age. Nevertheless, there is no significant difference in mortality risk between high- and low-status non-adults. For adults, the survival and mortality risk patterns of low-status males and high-status females show a significant difference. In particular, low-status males had an increased survivorship and lower risk of mortality compared to high-status females. Yet, there were no significant differences found between survivorship and mortality risk of low- and high-status adults combined, low- and high-status males, low- and high-status females, and low-status females and high-status males.

Canterbury was known for supporting the pilgrimage culture during the medieval period (Lincoln, 1955; Lyle, 2002). Pilgrims frequently

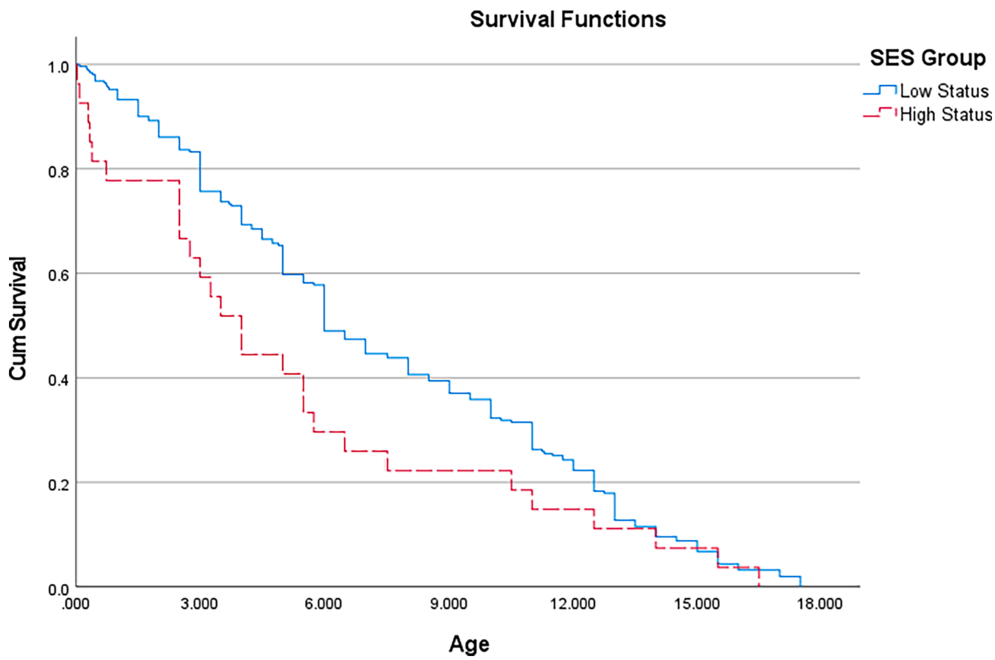

Fig. 3. Kaplan-Meier survival curve of high- and low-status non-adults.

Table 4
Log Rank (Mantel-Cox) test of high- and low-status non-adults.

X^2	df	P value
3.961	1	0.047[1]

[1] Significant.

Table 5
Cox regression analysis of high- and low-status non-adults.

Covariates	B	Exp (SE B)	df	P-value	Hazard ratio (95 % CI)	VIF
High- × Low-Status	−0.385	0.203	1	0.058	0.681 (0.457–1.014)	1.000[2]

[2] No correlation.

Table 6
D_{30+}/D_{5+} values and 95 % comparison intervals for the low- and high-status groups.

	D_{30+}/D_{5+}	95 % CI
Low-status	0.3888	0.2767–0.5009
High-status	0.3548	0.2318–0.4778

travelled to Canterbury for protection from anything harmful or to become cured from ailment (Hopper, 2002; Lincoln, 1955; Lyle, 2002; Webb, 2000). The people of Canterbury would have provided pilgrims with accommodation within inns or homes (Lincoln, 1955), and food and drink at carts, stalls, taverns, or inns (Hopper, 2002; Lincoln, 1955), and souvenirs such as fake blood of saints for healing or miracles (Miller and Hatcher, 1995) in return for monetary needs (Hopper, 2002; Lyle, 2002). This perhaps gave low-status people the opportunity to obtain a stable income (beggars may have been able to sustain the practice of begging due to frequent donations from the pilgrims), allowing a healthier lifestyle, such as food security, compared to the average low-status person in medieval England. However, similar to other medieval English towns, Canterbury had unhealthy living conditions such as compact housing and unsanitary waste disposal (Lyle, 2002; Rawcliffe, 2013). This environment provided a space for infectious and parasitic diseases to thrive (Barnes, 2005; Rawcliffe, 2013). The pilgrimage culture gave low-status people an even footing similar to high-status people who had food storage for harsh periods such as disease outbreaks and famines. This suggests that low-status people in Canterbury may have had adequate provisions to meet their dietary requirements to avoid being majorly affected by infectious diseases and nutritional deficiencies. Therefore, the absence of significant differences between the adults SES groups and SES groups in relation to biological sex, apart from high-status females and low-status males, maybe the result of society being advantageous for those of low SES due to the pilgrimage culture, resulting in similar survivorship and morality risk as high SES individuals.

The current study suggests that high-status females had higher mortality risk and lower survivorship compared to low-status males in medieval Canterbury. Low-status males perhaps had access to various nutritious foods, such as fruits and vegetables (Dyer, 2006), which would have made them less susceptible to diseases and poor health. Men of low-status consisted of local community members and potentially St. John's Hospital members (Sparks, 2001; Tatton-Brown, 1995). As a result of the pilgrimage culture, hospitals in Canterbury received an abundance of donations (Orme and Webster, 1995), allowing caregivers to provide hospital members with various nutritious food and physicians to purchase seeds of exotic herbs for the hospital's garden required for remedies (Carrott et al., 1994). In addition, low-status men of the community potentially made a high living wage that allowed them to obtain essential nutrients from a variety of nutritious foods. Adequate nutrition establishes an robust immune system to protect the body from various infections and nutritional deficiencies (Feigin, 1977).

Contrarily, the consumption of meat among high-status people was high before and after the Black Death (Woolgar, 2006). Lighter meats such as younger animals raised for husbandry, poultry, wild birds, rabbit, and deer were popular among women (Woolgar, 1999). A high consumption of meat can cause individuals to develop various poor health conditions such as high blood pressure, blood clots, heart disease, stroke, and diabetes (Feskens et al., 2013; Micha et al., 2010). It may be argued that meat consumption was less because it was not allowed on specific days and fish was more likely to be consumed as a result of the sovereignty that Canterbury Cathedral had over the city during the medieval period. However, there weren't any regulations on meat consumption and production established by the church in Canterbury (Lincoln, 1955; Martin, 1950). A study found that individuals who were buried in the priory had a higher average δ15N compared to those from the cemetery, suggesting those from the priory had a higher protein diet (Miszkiewicz et al., 2019). Additionally, due to the absence of hygienic health and safety regulations, various parasitic infections may have been obtained from meat infested with larva (Rawcliffe, 2013), incorrectly cured meat (Rubin, 1974), and improperly cooked fish (Mitchell, 2015). Godde and Hens (2021) found that there were no significant differences between individuals with a parasitic infection from various SES groups in medieval London. They suggest that due to the lack of hygiene, water contamination, food insecurity, inadequate nutrition, and parasitic load each SES group were affected similarly (Godde and Hens, 2021). It has also been suggested that women were more likely to ration out their food due to providing their husbands and children with most of it (Bardsley, 2014). The lack of consuming adequate amounts of food, specifically nutritious food, can cause malnutrition, nutritional deficiencies, anaemia, vitamin deficiencies, hypothyroidism, digestive disorders and other health conditions (Combs and McClung, 2016; Lee and Pearce, 2018; Moradi et al., 2018). Furthermore, pregnancy complications such as pre-existing disease or disease that developed during pregnancy (Hollis and Wagner, 2018; Lee and Pearce, 2018; O'Brien and Thomas, 2018), high blood pressure (Hedderson and Ferrara, 2008; Moser, 2007), haemorrhage (Goodwin and Breen, 1990; Mhyre, 2012; Shahbazi et al., 2012), and blood clots in the veins (Bourjeily et al., 2010; Mhyre, 2012; Stone and Morris, 2005) may have caused higher mortality risk and lower survivorship of high-status mothers and infants. These factors placed high-status females to have lower survivorship and higher risk of mortality compared to low-status males.

Low-status adults may have provided low-status children with adequate amounts of nutritious foods, especially fruits and vegetables. Fruits and vegetables were easily accessible and inexpensive, which influenced them to be often associated socially with being the diet of low-status individuals (Dyer, 2006). Conversely, meat was a preferred diet for high-status people (Woolgar, 2006). Meat consumption provides protein and important nutrients for normal physiological functions (Millwards and Garnett, 2010); however, excessive intake can cause poor health (Richi et al., 2015). A balanced diet with fruits and vegetables provides antioxidants that reduce the risk of impoverished health such as developing cardiovascular diseases (Nunez-Cordoba and Martinez-Gonzalez, 2011). As a result, high-status adults possibly provided high-status children with a less varied diet, including fewer fruits and vegetables, with other important nutritional content. In addition, high-status adults perhaps introduced food that was harsh for infants to digest that influenced prolonged stress during the early months of infancy (Miszkiewicz et al., 2019), thus, ultimately causing them to be more vulnerable to various gastrointestinal disorders (Heine, 2004; Parker et al., 1981) that lowered their survivorship compared to low-status non-adults. Gastrointestinal disorders that developed during infancy may cause functional gastrointestinal problems late in childhood (Partty et al., 2013). Additionally, gastrointestinal disorders, similar to other pathological conditions, extract an abundance of essential nutrients required for the development of the immune system to stimulate or boost immune responses to diseases (Heine, 2004). Inadequate nutrients may cause children to become more susceptible to diseases and death (Round and Mazmanian, 2009). The lack of adequate nutrients perhaps would have made high-status non-adults more susceptible to nutritional and infectious diseases especially during famines and disease outbreaks. On the contrary, the significant difference in survivorship perhaps is minor because there is no significant difference in mortality risk between high- and low-status non-adults. The log-rank test of the Kaplan-Meier analysis is purely a significance test, used to test differences in the crude survival between the groups, whereas the Cox regression provides an estimate of the size difference between the groups (Stel et al., 2011a, 2011b). The different statistical methodology between these two tests may contribute to conflicting results.

DeWitte and colleagues (2015) reported no significant differences between high- and low-status adults' survivorship and morality risk during early 18th to mid-19th century London. In contrast to the current study, they found that high-status children had increase survivorship and lower mortality risk compared to low-status children in industrial-era London (DeWitte et al., 2015). A suggestion that they made is their results reflects selective mortality due to hidden heterogeneity during childhood (DeWitte et al., 2015). Mortality is influenced by hidden heterogeneity, unknown factors that are not easily observable, which can be selective towards individuals with higher susceptibility to disease and death than other people in the same population (DeWitte and Stojanowski, 2015; Vaupel et al., 1979; Wood et al., 1992). It is possible to speculate that this may also be the case for this study since low-status non-adults had an increased survivorship compared to high-status non-adults. However, because there was no significant difference between nonadults SES groups' mortality risk then selective mortality cannot be indicated for this study.

4.1. Limitations

It can be assumed that migration affected the results of survivorship and mortality risk of both SES groups. Canterbury was a thriving urban centre resulting from theology and the pilgrimage culture that influenced migration (Lincoln, 1955; Lyle, 2002). Often, clergy members migrated from other parts of England and Europe to Canterbury for theological education or practice. For instance, Archbishop Lanfranc was born in Italy and lived in France before moving to Canterbury (Cowdrey, 2003), and Archbishop Thomas Becket was born in London and relocated between Normandy and Canterbury (Hutton, 2014). Also, migration patterns to urban centres mostly consisted of young women and adolescents (Dyer, 2002; Miller and Hatcher, 1995). Hence, both SES groups may include migrants within the city. Perhaps the individuals who migrated experienced similar adverse environmental conditions during childhood as medieval Canterbury's urban environment, thus influencing the lack of differences in survivorship and mortality risk for the adult groups. Another migration issue may be that high-status individuals were relocating from Canterbury to other places. It can be argued that the small sample size of the high-status group compared to the low-status group may have impacted the results of survivorship and mortality risk patterns. However, due to the non-parametric and semi-parametric nature of the statistical test sample size perhaps had a minor effect on the results. Nonetheless, this study offers an understanding of how lifestyle differences between SES groups effects mortality and survivorship in medieval Canterbury.

5. Conclusion

This study indicates low-status non-adults had increased survivorship compared to high-status non-adults, and low-status adult males had increased survivorship and lower risk of mortality compared to high-status adult females. High-status children potentially did not receive adequate nutrition from their mothers through gestation or breastfeeding. In addition, as a result of high meat consumption for high-status individuals, the lack of sufficient amounts of essential nutrients from food such as fruits and vegetables, required for their developing immune systems, would have made them more susceptible to infections and nutritional diseases. The survivorship differences between the non-adults SES groups may be minor due to there not being a difference between mortality risk. The differences between survivorship and mortality risk of low-status adult males and high-status adult females are perhaps reflective of the benefits the pilgrimage culture provided for low-status individuals and the inadequate nutritional lifestyle choices of high-status women. High-status women possibly neglected to consume adequate nutrition that led to poor health. The constant influx of pilgrims made resources readily available for low-status individuals because of the continuous need to provide resources for the new arrivals in the city.

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CRediT authorship contribution statement

Sina D. White: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Patrick Mahoney:** Resources, Supervision. **Chris A. Deter:** Resources, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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